DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Pulp and Paper Industry Challenges Chemical Engineers

IN Canada pulp and paper is the largest industry. It ranks first in employment, in total wages paid, in capital invested, in value of production and in value of exports. Its production is worth $1.4 billion per year and this is seven per cent of the value of the output of all Canadian industry. Little wonder that its problems and prospects formed the subject of a bustling, lively address by DR. L. R. THIESMEYER when the Society of Chemical Industry held its Annual General Meeting in Montreal. The impact of modern chemical technology upon the pulp and paper industry has been to initiate three major, quite revolutionary trends which are already well established and which will make enormous changes in operating practices and capital plant. These trends are:

(1) the merging of mechanical with chemical pulping;

(2) the conversion of chemical pulping from batch to continuous operations at high speeds; and

(3) the processing of by-products from the liquid wastes.

DR. THIESMEYER looked forward to the day when the industry would become not only a major user of chemicals but also a major producer of them. His survey led up to a final recruiting peroration pointing out that the pulp and paper industry offers to young chemists and chemical engineers opportunities virtually unlimited for interesting and rewarding careers. These may lie in maintaining and increasing the flow of chemicals to the greatly expanded manufacture of pulp and paper—for cooking, bleaching, sizing, coating, for water treatment, lubrication, pitch and slime control and so on. They may lie in extraction of a host of chemical values from the liquid and solid wastes of the industry, or they may reside in the challenge of producing synthetic cellulose and lignin from non-viable substances, as cheaply as this can be done in the manufacturing plants of nature.

Platinum Materials Increase Acid Resistance of Stainless Steel

SHALL we ever go over to adding platinum to stainless steels as a method of improving acid resistance? This possibility—at first glance so economically impracticable—is suggested by recent Russian work on assisting the passivation of 18-8 type stainless steels in aqueous sulphuric acid by adding small amounts of noble metals, especially platinum and palladium. A convenient summary has appeared in *Platinum Metals Review**. The work stems from the modern theory of passivation. Briefly, it is thought that when a metal is made the anode in an acid solution there is a certain limiting potential and limiting current density at which the production of sparingly soluble oxides becomes thermodynamically possible, and kinetically easier than the formation of a soluble product. This is partly because the limit of its solubility has been reached in the layer of acid solution adjacent to the anode. The new product is formed as a compact layer on the anode surface, and provided that the anode potential remains more positive than the limiting value, the metal is protected from all but the smallest attack, being termed "passive" or "passivated." Chemical passivation of a metal, without the necessity of an external cathode to send current to the anodic zones, is readily achieved if the acid solution contains a cathode reactant that can react rapidly by cathodic reduction on the metal itself, so producing the necessary rise of potential and high-current density at the anodic zones.

If the surface of stainless steels could be made much more catalytically active for the cathodic reduction of oxygen or, still better, of hydrogen ion, larger current densities at more positive potentials could be obtained at any anodic zones. The Russian workers TOMASHOV and MME. CHERNOVA therefore prepared stainless steels containing small additions of noble metals designed to provide especially active cathodic zones for such reactions. Using as a basis a commercial 18% chromium, 9% nickel-alloy steel, they added respectively 0.1% platinum, 0.1% palladium, 0.9% palladium and 1.2% copper. The alloying additions were increasingly effective in the order Cu-Pd-Pt, and the increase of palladium content from 0.1 to 0.9% gave a further useful increase in effectiveness. However, 0.1% of platinum was at least as effective as 0.9% of palladium except at the highest acid concentration.

The article suggests that for comparatively small components where maximum acid resistance is required such an alloy might well be economically competitive with titanium and other refractory metals.

*1958, Vol. 2, No. 4, p.117.

University Training: Facts and Policies

TOTAL student membership at British Universities rose from 50,246 in 1938-39 to 94,600 in October, 1957. The Government's plans for the future are based on recommendations from the University Grants Committee for a planned expansion to 124,000 full-time students by the mid-1960s with a further 10% in the second half of the decade. Two-thirds of the expansion is expected to be in science and technology, which would result in an increase in student numbers in those faculties to 55,000 by the mid-1960s, an increase of 86% over 1955-56, the year taken as the base for planning. These are among the facts presented in the U.G.C. report on university development, 1952 to 1957*. Between 1953-54 and 1956-57 the numbers of entrants to courses in science and technology rose by 34%, about double the increase in the number of entrants to arts courses. These considerable achievements need to be considered with the pinch of salt ably administered by SIR HUGH BEAVER in this year's Presidential address to the Institution of Chemical Engineers; after examining plans for educational expansion at all technical levels, SIR HUGH concluded that we

shall be short of scientific manpower throughout the next two decades. But policy matters as well as numbers and we commend the view of the U.G.C. that "the first duty of the university to the student is to teach him how to think. For this purpose he must be given not only competence in one field of knowledge, but access to related fields and a general appreciation of the art of learning. He must therefore be helped to acquire interest outside his special subject, and he must be given time and opportunity to take part in the mutual education of student by student which is one of the most valuable benefits of university life". We would not consider that this falls in the category denounced by PROF. P. V. DANCKWERTS, in his inaugural lecture, of teaching a man to live on his wits. Competence in his own field is essential to the student but he will be a better man if he also knows how to approach unknown territories.

*University Development—Report on the Years 1952 to 1957. H.M.S.O. Cmnd. 534. 5s. 6d.

Learning by Doing

BUT graduation is only a prelude to professional education. It must be followed—in the case of chemical engineers—by practical training in industry and at a more senior stage by experience in a post of responsibility. As long as most graduates were liable for call-up, there was often difficulty in persuading firms to organise coherent formal schemes of practical training. However the successive decisions of the Ministry of Labour in 1956 and 1957, relaxing the regulations governing deferment for graduate engineers, transformed the situation. The industry developed an interest in organised schemes and the Institution of Chemical Engineers has now issued a guide for training the graduates on a broad practical basis. Its object is to show the graduate "not only how to apply his academic knowledge but also how chemical engineering is integrated into the structure of industry, with special reference, of course, to the industry he has chosen for his own. The training is both complementary and supplementary to his university training." The resulting suggested schedules include training in process plant fabrication, development, design and operation. Several months are allotted to each of these subjects and throughout it is urged that attention should be drawn to the importance of cost. This guide, which we would strongly recommend, is intended to assist those who wish to prepare schemes for their graduate trainees. It results from consultation with the Association of British Chemical Manufacturers and the British Chemical plant Manufacturers Association and, we understand, has the general approval of these bodies. It is published in *The Chemical Engineer* August, 1958, p.43.

Pressure Drop, Heat and Mass Transfer in Columns with Raschig Rings

USING a packing of 16 mm Raschig rings H. SCHRADER has reported that three flow-regions exist on the gas side in counter-current, liquid-gas flow in packed columns. The extent of these regions is identical for pressure drop, heat transfer and mass transfer—so that different laws exist for these properties respectively in each of the regions. No special names are given to these regions, other than lower, middle and upper, but the different constants and exponents for the equations used are tabulated.

DIPL. ING. SHRADER completes his paper* by comparing his results with those of other workers and discusses possible reasons for differences. Air and water were employed as the experimental gas and liquid respectively. Effective column diameter was 226.5 mm and the packing was mounted on a sieve. Gas flows ranged from about 400 kg/m²hr to about 5000 kg/m²hr, and pressure drops in mm w.g. per mm from about 3 to 1000. Liquid flow rates extended from 1 m³/m²hr to about 20 m³/m²hr.

**Kältetechnik*, 1958, Vol. 10, Part 9, p.290.

Complaint Against Alkali Act Standards

AN accusation that clothing was damaged by mist from a sulphuric acid works was made at the recent conference of the National Society for Clean Air. MR. J. LAW, a vice-president of the society, claimed that this occurred despite the fact that the effluent complied with the Alkali Act requirements. The facts had been drawn to the attention of the authorities but they were not prepared to alter the regulations. MR. LAW was moving a resolution claiming that the concentrations of acid gas permitted by the Act are "greatly in excess of what ought to be permitted in the present drive for cleaner air, that the discharge of acid gas within these tolerances can and does cause great discomfort and distress to persons within the area of discharge." Source of the discharge was said to be the NCB Avenue carbonisation plant near Wingerworth. This was causing trouble of various types but the worst was that from the acid plant. The NCB was said to have been most co-operative; they had agreed to increase the height of the chimney and introduce an electrostatic precipitation plant at a cost of £45,000, but the fact that their discharge was not over the standard suggests that some of the standards set out in the Alkali Act need revision.

It would be interesting to know if similar difficulties had been reported from other districts and to have an indication of the nature of the Government's evidence on this subject.

Coal: Many Kinds of Stocktaking

FINANCIAL difficulties facing Britain's coal industry were recently described by SIR JAMES BOWMAN as "really serious." The chairman of the National Coal Board added that they were confronted with a formidable problem of disposals due to the sudden decline in demand. This is not peculiar to Britain. The U.N. Economic Commission for Europe has reported that pithead stocks are rising in many European countries. Over a year ago (*British Chemical Engineering* October, 1957, p.526) we referred to the first rumblings of this crisis and urged that greater weight should be applied to projects for exploiting the chemical possibilities of the mineral. Brief references to some of these lines of work were made in the Thornton lecture by MR. A. H. A. WYNN—Scientific Member of the Coal Board—who also pointed a moral about choosing the right tempo. Apparently a chemical engineering contractor has recently made a design study of a large plant for the conversion of low-grade East Midland coal into premium motor spirit, diesel oil and town gas. This study described a plant to convert 2.3 million tons of solid fuel into about 630,000 tons of oil products a year and 56 million cu. ft of town gas per day, representing a thermal conversion efficiency of 61%. The plant included two main stages: the first stage gasified the whole coal with steam and oxygen to produce a mixture of hydrogen and carbon monoxide at a pressure of 25 atmospheres; the second stage employed Fischer Tropsch synthesis to produce hydrocarbon liquids and gases. The coal containing 15% of ash cost 3.1 per therm and the purified synthesis gas 7d. a therm, leaving a sub-

stantial margin for the rest of the process. The estimated capital cost was about £35 million including working capital and the estimated gross annual return was 20% on the capital. If this challenging project could be realised, it would provide a market for small low-rank coal. MR. WYNN commented that attitudes taken to it illustrate the twin dangers of extreme pessimism—fear of new ideas—or facile optimism. Detailed examination has shown that a pressurised slagging gasifier is fundamental to the whole project but the type envisaged has not yet been made. Such a gasifier must be built and tried out before the project can go much further, and this is being done by the British Coal Utilization Research Association, the Gas Council and contractors.

**The Mining, Electrical and Mechanical Engineer*, 1958, Vol. 39, No. 455, p.39.

Progress in Graft Polymerisation

IF you take a macromolecular chain—which may be a homopolymer, a statistical copolymer, a block co-polymer or a polycondensate—and put side-chains on to it, the product is called a graft polymer. The side-chains are usually of different composition from the main chains. The special value of graft co-polymers is firstly that the molecular structure is branched and secondly that in the same molecule there are present chains of quite different properties. In *Kunststoffe**, DR. P. PIGANIOL, has now briefly reviewed this field. The reactions can be carried out by "pure" chemical methods by photolysis or by the use of penetrating radiation. In general terms it is obvious that this provides fresh opportunities for investigating desirable combinations of physical or chemical properties. DR. PIGANIOL gives specific examples. It is difficult to mix P.V.C. with polyacrylonitrile (P.A.N.). The mix is kneaded at 160-180°C, but yields an opaque heterogeneous white material with granular structure and valueless mechanical properties. A higher temperature causes decomposition of the P.A.N. but co-polymerisation provides a means of making the two materials miscible. If even a small proportion of acrylonitrile is grafted on to P.V.C. the resulting graft co-polymer can carry large admixtures of P.A.N. yielding a homogeneous, transparent mass with good physical and mechanical properties. A further important field of use is in altering surface properties, such as improving fastness to ozone and ultra-violet light, or reducing the tendency of nylon to retain static electricity.

*1958 Vol. 48, Part 9, p.398

Continuous pH Measurement

OVER the past twenty-five years continuous *p*H measurement has steadily increased in use and importance. The equipment for measuring *p*H has developed from temperamental laboratory adaptations to well-engineered industrial designs. Recent developments forming part of this change have been described by D. BROOKS and his colleagues* in a paper mainly concerned with measurements at high temperature, high pressure and high *p*H. A design of calomel electrode which has both a long life at high temperatures and a reasonable transient performance consists of a short piece of 5mm-bore, lead-glass tube closed at one end; a short piece of platinum wire is formed into a helix inside the tube and sealed into it. The other end of the platinum wire forms the contact. The helix inside the electrode is thoroughly amalgamated and surrounded by a small bead of mercury. A paste of electrolytic mercury/calomel emulsion and finely crystallised potassium chloride is added and the whole tightly packed and retained by an inert wad of cotton wool. The saltbridge consists of a flexible moulded-rubber sac, the open end of which fits tightly over the glass tube of the hole in the lower end of the sac and forms a liquid junction having a low diffusion rate. After test use at high temperature for three months no sign of drift was observed. The programme included an investigation of the reason for failure of calomel electrodes under cyclic-temperature conditions and the proposed new design of electrode was shown to withstand these conditions. The measurement of *p*H under pressure is a problem intimately connected with the design of the calomel electrode and this, in turn, involves special consideration in the design of the measuring-electrometer system. A further novel problem discussed is that of *p*H measurement in a solution of very low ionic concentration—as in the case of heavy water moderated nuclear reactors. In this case incidentally it is more accurate to refer to the property as *p*D rather than *p*H. The purity is very high and may correspond to a conductance of 0.05 reciprocal megohms. The dissociation constant is lower than that of ordinary water, being 2×10^{-15}. To cope with these conditions and the difficulties arising from it MR. BROOKES recommends a flow cell which prevents potassium chloride from the saltbridge from diffusing back to the glass electrode at the low flow of 10-15 cm^3/h. This can be achieved by introducing a polythene capillary tube, separating the liquid round the calomel half-cell from that round the glass electrode.

**Instrument Engineer*, 1958, Vol 2, No. 6, p.105.

Fewer Industrial Accidents

BETTER methods of work and the application of effective safety measures are considered by the Chief Inspector of Factories to have been major factors leading to improvements in the industrial accident figures. In 1956 there were 184,785 accidents—687 of them fatal. The corresponding figures for 1957 were 174,713 and 651 although the total employment figures showed little change in this period. Accident frequency rate per 100,000 manhours—based on incomplete figures—was 1.611 taken over all industries. In the classification used in the Chief Inspector's Annual Report for 1957, coal tar and petroleum refining have a rate of 2.07, other chemicals and artificial fertilisers 1.04, while the group paints, colours and varnish shows a figure of 1.73. There have been a number of examples during the past year of the replacement of dangerous materials by others of a less dangerous nature. Some of the more important are steam replacing benzene for the extraction of fat from bones, methylated spirit replacing isopropyl alcohol for foundry mould-facing compounds and liquid sulphur replacing dry sulphur to reduce risks of explosion.

Developments in the use of ionising radiations present new problems. It is probable that at present the hazard to health of workers is greatest where sealed sources are being used for radiography and fluoroscopy. In their application as static eliminators or thickness gauges, sources emitting beta rays such as strontium 90 or thallium 204 are usual. The hazard with such sources is chiefly in handling them when a machine is being dismantled for maintenance or to remove the source. In radiography, however, gamma ray emitters are employed such as iridium 192 or cobalt 60 and, recently, caesium 137 has become popular because of its longer half-life.

This year the report has been presented in a new form. Length has been reduced to about one quarter of that of earlier reports and the composition recast. As part of the new look research on safety is extensively reviewed. D.S.I.R. work in its own stations and at Research Associations is summarised together with such items as research on pressure vessels at individual companies. This feature is likely to make the document above-average in its value and interest to Industrial Safety Engineers.

Using Electricity Safely

AT a recent meeting of the society of Instrument Technology, MR. S. J. EMERSON presented a compendious survey of electrical safety. Opening with a summary of the relevant Statutory Regulations, MR. EMERSON, who is Senior Electrical Inspector of Factories, went on to consider the nature of the dangers and the best ways of meeting them. The whole of this paper, clearly illustrated with circuit diagrams, will be valuable to operational engineers, particularly when there is increasing use of electrical control gear and automatic process control. But there may be special interest in the discussion of "intrinsically safe electrical equipment." It should be noted that because a circuit has been certified as intrinsically safe it does not necessarily follow that the whole of the apparatus associated with it can be used in a hazardous situation; in fact, one of its most important applications is to form a bridge between normal equipment in a safe area and components which are in a danger area. The most important units subject to this limitation are the relays or coupling units used in operating circuits, and transformers and power packs supplying intrinsically safe circuits from normal power circuits. All these, unless specifically certified as of flame-proof construction, must be located in a safe situation. It should also be recalled that the classification of gases for intrinsically safe apparatus which is defined in B.S. 1259: 1945 —is different from the grouping of gases adopted for flame-proof apparatus, described in B.S. 229: 1946. This is due to the fact that the physical processes in the ignition of gas are different for intrinsic safety from those which apply to flame-proofing.

Statistical Study of Corrosion

AN ambiguous term is "statistics." But strictly in the sense of mathematical analysis of data, a statistical study of corrosive damage to the base of a storage tank for hydrocarbons has led to recommendations on the plate thickness for a replacement. Details are given by CL. MEYER in a recent issue of *Corrosion et Anticorrosion*, 1958, Vol. 6, No. 9, p.298. Designers wished to have some precise information about the corrosion of the old tank before it was dismantled. The base was therefore sampled by removing 52 portions each 28 mm. in diameter with a suitable drill. After a preliminary micrographic examination of six of these, all were measured by point-ended calipers to determine residual plate-thickness between the bottoms of corrosion pits and with plate-ended calipers to determine the superficial plate-thickness. But uniform corrosion as well as pitting had probably taken place, so that the thickness measured in this manner was unlikely to be the original thickness. The original thickness was obtained from examining a number of lap-joints. It was assumed that the covered surface in the overlap of the joint had not been attacked. M. MEYER stresses that the average loss-figure did not offer a design basis. The three groups of figures had to be analysed to find the worst example of attack. Over the 20 year life of the tank it was estimated that the 10 mm. plate had lost 0.70 mm. After examining the ranges of the figures, M. MEYER did not think it necessary to suggest an increase of thickness of more than one millimetre in the new tank to allow for corrosion loss. Finally the whole programme was cross-checked when the damaged reservoir had been dismantled by a further sampling programme of 168 measurements on base plates and 89 measurements on the wall.

This interesting study naturally carries a warning disclaimer; the forecast rests on the assumption that corrosion will continue in the future at the same rate in the same way as in the past—despite new products and replacement of a basic Bessemer steel with an open-hearth steel.

Upgrading Minerals by Electrochemical Methods

ELECTRO-REDUCTION at high current density may be used to whiten diatomites and china clays mainly by part-removal of the original Fe_2O_3 content. This was the main conclusion of G. GRUDER* *et al* after a study in which the effect of electrochlorination treatment was also examined. The latter involves the electrolysis of NaCl to produce "active" chlorine at the anode which then oxidises the organic impurities and thus raises the degree of whiteness of the material. Graphite anodes and iron cathodes were used in electrochlorination. Diatomite was charged into the anode compartment of a cell together with a solution of NaCl (300 g/l) in the proportions of 50 g diatomite to 200 cc of NaCl solution. The effect of temperature, current density and superposition of an a.c. current on the d.c. current on the degree of whiteness were investigated. In the case of electroreduction anodes of pure lead and cathodes of amalgamated lead were used. The material was charged into the cathode compartment and a 1% solution of sulphuric acid was used as an electrolyte. This led to a fall in Fe_2O_3 content from 2.57 to 0.53 and an accompanying gain in whiteness which was objectively measured. Detailed investigation of the variables led to recommendations that the temperature should exceed 60°C, ratio of mineral to electrolyte be kept low and that electrodes with very high hydrogen over-voltage should be employed, such as amalgamated lead.

**Revista de Chimie*, 1958, No. 7-8, p.361.

Automatic Water Hardness Monitor

A MECHANISED version of the laboratory test for hardness using EDTA with "Solochrome Black" as the indicator, has been applied for automatic inspection of boiler feed water. The apparatus was designed primarily for automatic detection of an increase in the hardness of the water from a treatment plant beyond a pre-set figure and to give an alarm when this occurred. The end point, a change of colour from puce to slate blue, is viewed by a selenium photocell. No synchronous motors are used, the device being entirely automatic, and the frequency of the tests can be varied from one every two minutes to one every hour. Details of the arrangement are given by W. H. PARKER and G. M. BOND in *The International Sugar Journal* (1958, Vol. LX, No. 718, p.288).

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British Chemical Engineering
A HEYWOOD PUBLICATION

Industrial Leadership

WHAT makes a leader? Are leadership qualities innate or acquirable? Can they be learnt from the captains of history and industry, or from sociology, or from both sources? What are the moral issues of leadership? Will the techniques of leadership be abused, resulting in systems foreseen by Orwell and attacked by W. H. Whyte in his "Organisation Man"? This kind of question has been spotlighted by, within a few decades, two world wars, the rise and fall of dictators and an explosive expansion in technology—the last not least in our own country.

Management and leadership are as important to the industrial world as they are to the world of nations—indeed, the two worlds are becoming increasingly closely identified. Industry not only has to find good managers for its present needs but it is also burdened with the duty of providing for its future leaders. More and more it is calling for technically trained people having leadership abilities that match their special skills and knowledge. Such people are scarce, whether at managerial or foreman level, and Sofer and Hutton, in their newly published description of a management experiment at the Production Engineering Department of Acton Technical College (Tavistock, 1958), stigmatise as "under-developed areas" those parts of industrial manning that require the dual qualifications. Without doubt, there is room for improvement in the present situation, and the recent growth of the concept of managership as a profession to be studied and mastered may be a sign that industry is prepared at least to examine the latest intellectual equipment, no matter how unconventional.

The most obvious method of analysing leadership is to try to isolate the characters or qualities of behaviour that go to make a leader. Field-Marshal Sir William Slim, for example, has advanced, in order of importance, the qualities of courage, physical and moral; will-power; flexibility of mind; knowledge—to appreciate the difficulties of one's subordinates; and integrity. L. F. Urwick has collected a number of the traits of character considered most important by other outstanding leaders, civil and military. They include persuasiveness, decisiveness, intellectual capacity, common sense, responsibility, health, youth and vitality. For social scientists, however, these qualities were too vague and difficult to measure, and on both sides of the Atlantic they approached the mystery of leadership by specialised methods.

The first big leadership project to be tackled on those lines was the establishment of the War Office Selection Boards for officers during the Second World War. The degree to which social scientific help is now being supplied to industry is indicated by the fact that in Britain the Tavistock Institute of Human Releations alone is engaged on management consultant activities on a budget level of about £25,000 annually. Their "social analysts" work only with the unanimous agreement of staff and management, and outstanding amongst their undertakings is the experiment conducted at the factory of the Glacier Metal Co., London, to discover how far democratic rights inside an industrial organisation can assist the management to manage. Recently, Institute workers have developed an important "socio-technological" concept as a result of studying the effect of technical changes on social structure in industry. In the field of recruitment, selection, training development and promotion, the Institute's biggest project is their work with Unilever during the past ten years.

Some of the latest notions on leadership elaborated chiefly in the U.S.A. were outlined at a conference for executives in London, recently organised by the British Institute of Management and addressed by Professor Robert Tannenbaum of the University of California. The views he stated command attention if only for the wideness with which they were accepted by the conference. He started by regarding people as individuals and urged that industrial leadership should be centred on building lively and productive organisations founded upon and enriched by individual variation. Organisations should be improved by personal improvement, through allowing individuals to come to grips with their hidden problems that obstructed useful thoughts and actions. The essence of his theory lay in two principles. First, that the personality of the subordinates and the circumstances of each situation were involved in leadership equally with the personality of the leader, and, second, that leadership was closely associated with two recently discovered deep-seated traits. These were (a) ability to understand another individual or situation accurately without seeing only what one wished to see, and (b) the flexibility to act appropriately once one has understood a situation. Here, however, he provided a ray of hope for those not amply blessed with these qualities, for university courses were being made available in America to enable executives to resolve some of their own problems and become more effective personalities. This idea has already crossed the Atlantic and, in fact, a similar course was held at Leicester University recently with the co-operation of the staff of the University of California and the Tavistock Institute.

As to the managers' dilemma of whether leadership should be authoritarian or democratic, there was no ready-made solution, Professor Tannenbaum said. There existed, in his opinion, a continuum of leadership behaviour progressing from the "authority centred" side to the "subordinate centred" side, at the extreme of which the group defined its own limitations and arrived at its own decisions. At which stage of co-operation with subordinates a manager worked depended on the particular circumstances of the situation. Professor Tannenbaum declared himself to be biased toward the democratic end of the continuum and he had found that the more mature leaders and led were, the more they preferred to work at that end too.

The more sophisticated qualities that appear now to be looked for in leaders include maturity and intelligence, the ability for policy thinking and for looking ahead, the facility to give and take while in a position of power and the courage to face up to the appointing of successors.

66.061.5

ANALYSIS OF BATCH-OPERATED EXTRACTION PROCESSES—PART I

A summary of methods of operating batch extraction processes and an account illustrated by worked examples of methods of analysing their performance

by G. V. JEFFREYS

A BATCH-OPERATED solvent-extraction process offers distinct possibilities in chemical processes in, for example, the fine chemical, pharmaceutical, and antibiotic industries when it is necessary to treat small quantities of materials for the recovery of expensive products, and where the temperature of distillation would harm the product, or where the physical properties of the mixture make separation by distillation impossible.

There are two general types of batch solvent extraction processes. The first, frequently termed differential extraction is principally a laboratory method, but is capable of moderate scale-up to the size of a small commercial unit. Differential extraction should only be employed when the phase equilibrium properties of the substances being treated are such as to give a type 1 triangular phase equilibrium diagram (Fig. 2). The second type of process is an extension of the first, and is a multi-stage extraction process operated batchwise.

Types of Solvent Extraction

Batch Differential Extraction. This process is in many respects similar to differential distillation. The extract is removed from contact with the raffinate as soon as it is formed, just as the vapour and liquid are immediately separated in differential distillation. A typical differential extraction process is illustrated in Fig. 1 and it is suitable for operation with a solvent of density lower than that of the raffinate phase. The charge to be extracted is placed in the extraction vessel which is provided with an efficient agitator and the extracting solvent is slowly admitted into the base of the charge vessel. Some solvent dissolves in the charge, saturating it, and the excess passes through the agitated mixture, picking up solute as it does so, to form a layer of extract on the raffinate surface. This extract overflows into the solvent regenerator, producing the extract product which is recovered. The solvent is recycled and re-used.

Treybal[1] shows that for a solute C dissolved in a carrier liquid A, which is extracted with a solvent B, the weight of solvent necessary to saturate a charge of F lb. of mixture of C in A is:—

$$\textit{Weight of Solvent to saturate charge} = F\left[\frac{\text{Line } FR_o}{\text{Line } R_oB}\right] = F\left[\frac{x_{BR_o}-x_{BF}}{x_{BB_1}-x_{BR_o}}\right] \quad \ldots.(1)$$

where x represents weight fraction, the first suffix signifies the component B and the second suffix represents the particular stream, F = feed or charge, R_o = initial raffinate, and x_{BB_1} represents weight fraction of solvent in solvent phase (Fig. 3).

Treybal[1] further shows that the relationship between the weight of initial raffinate R_o when the differential extraction starts, and R_f the final weight of raffinate is:

$$\text{Log}_e\frac{R_o}{R_f} = \int_{x_{CR_f}}^{x_{CR_o}} \frac{dx_{CR}}{(x_{CB}-x_{CE})\left[\frac{x_{CB}-x_{CR}}{x_{CB}-x_{CE}} - \frac{x_{AB}-x_{AR}}{x_{AB}-x_{AE}}\right]} - \int_{x_{AR_f}}^{x_{AR_o}} \frac{dx_{AR}}{(x_{AB}-x_{AE})\left[\frac{x_{CB}-x_{CR}}{x_{CB}-x_{CE}} - \frac{x_{AB}-x_{AR}}{x_{AB}-x_{AE}}\right]} \quad \ldots.(2)$$

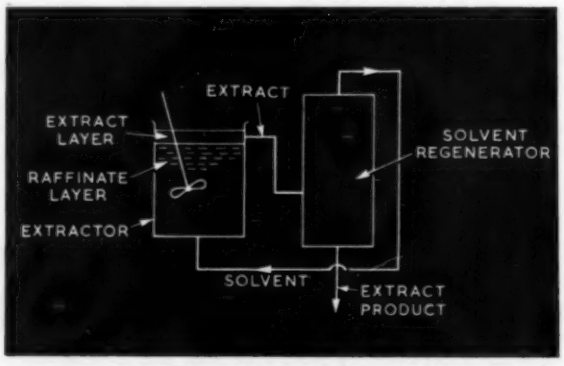

Fig. 1. Flow diagram illustrating a typical differential extraction process. It is suitable with a solvent of lower density than that of the raffinate phase.

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Both the integrals in Equation (2) must be evaluated graphically. Treybal[2] illustrates the use of Equations (1) and (2) with a numerical example.

Batch Multi-stage Extraction. If the liquid system that is to undergo a batch extraction displays a type 2 phase-equilibrium diagram, a differential extraction will not provide a greatly enriched product, but if the extract phase (from the differential extractor) is fed into the base of a multi-stage column, and the reflux is admitted to the top stage, a considerable enrichment should ensue. The use of reflux is common to continuous extraction operations where the liquid system being treated has a type 2 phase equilibrium curve. Hence, when small quantities of materials are to be extracted, and when their physical properties are such as to give an equilibrium relationship of the type shown in Fig. 4, multi-stage batch liquid-liquid extraction should be employed.

Symbols Used

A = solute carrier liquid
B = extracting solvent
C = extractable solute
E = extract in lb.
N = lb. solvent/lb. solvent free liquor $B/(A + C)$
P = extract product in lb.
R = raffinate in lb.
Q = net flow in lb.
X = weight fraction on solvent-free basis.

Suffixes

AB = carrier liquor in solvent
AE = carrier liquor in extract
AR = carrier liquor in raffinate
CB = solute in solvent
CE = solute in extract
CR = solute in raffinate

1, 2, 3, ... to n = stage number.

General Batch Process

A typical batch solvent extraction process is illustrated in Fig. 5. The particular arrangement is suitable for treating a charge of liquid with a solvent of lower density. If the solvent is denser than the liquid to be extracted, the charge vessel would be placed at the top of the column and the solvent regenerator at the bottom. In Fig. 5 the charge vessel is shown as an integral part of the column. This is the simplest arrangement, but of course, the charge vessel could be a separate item, with the necessary piping connecting it to the column in much the same way as an external reboiler is fitted to the base of a distillation unit. The column may be a plate or a packed column. Pratt[3, 4] gives a full description of the different types of processes and equipment suitable for batch solvent extraction. In the process illustrated in Fig. 5 the batch of liquid to be extracted is charged into the charge vessel and agitated. Solvent is slowly admitted into the base, and is mixed with the charge. If the charge is not saturated with solvent, that is, it is not a point on the equilibrium phase curve, the initial portions of solvent will dissolve until the charge solution is saturated. Thereafter solvent will rise through the raffinate layer, absorbing solute and forming an extract layer above the raffinate. With continued addition of solvent to the bottom of the unit, the extract emerging from the raffinate is forced up the multi-stage column where it is further enriched through mass transfer from the descending reflux. The final extract leaving the top of the column passes to the regenerator. The regenerated solvent is recycled, and the extract product is divided, partly to product and the remainder returned as reflux.

The above description of the batch extraction process shows that in operation it is very similar to a batch distillation and like the latter it can be operated, with a constant reflux ratio, to yield an extract product whose composition varies with time, or the reflux ratio may be adjusted continually during the process in order to maintain the composition of the extract product constant. Each of these methods of operation will now be analysed.

Analysis of Multi-stage Extraction

The initial drops of solvent that are dispersed into the solution in the charge vessel dissolve to form a saturated raffinate, and the amount of solvent required to form a saturated raffinate can be calculated by Equation (1). Once saturated raffinate has been formed, all the solvent fed into the bottom of the charge vessel will appear as extract phase above the raffinate and will pass up the column. Hence, provided that the solvent recycling rate is constant, and in an actual operation this would be so, the rate of flow of solvent up the column will be constant during the whole of the extraction period. Consequently any analysis is best made on a solvent-free basis.

Thorough agitation should be maintained in the raffinate vessel during the entire extraction, so that the extract leaving the raffinate layer is always in equilibrium with the raffinate. This may be difficult to attain in practice but for the purpose of this analysis equilibrium of extract and raffinate will be assumed.

When the raffinate has been saturated with solvent and the batch extraction has begun let the quantity of solvent-free raffinate in the charge vessel be R. Let a differential amount of solvent enter the base of the charge vessel which

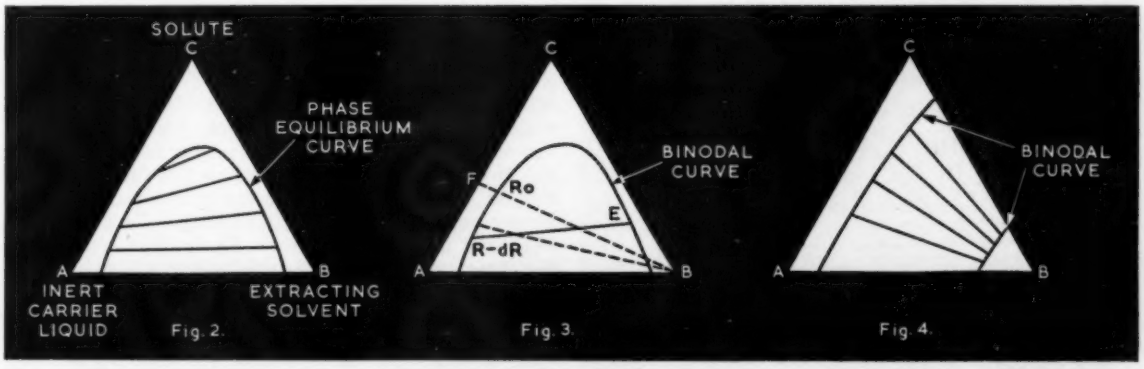

Fig. 2. A type 1 three-component equilibrium diagram.

Fig. 3. Differential extraction on three-component phase diagram.

Fig. 4. A type 2 three-component phase equilibrium diagram.

infers that a differential amount of extract product dP of composition X_{CE} (on a solvent-free basis) leaves the top of the column. This means that the quantity of raffinate in the charge vessel becomes $(R - dR)$

$$\text{and } dP = -dR \quad \ldots.(3)$$

also a solute balance gives

$$X_{CE}.dP = -d\ (RX_{CR}) = -(RdX_{CR} + X_{CR}.dR) \quad \ldots.(4)$$

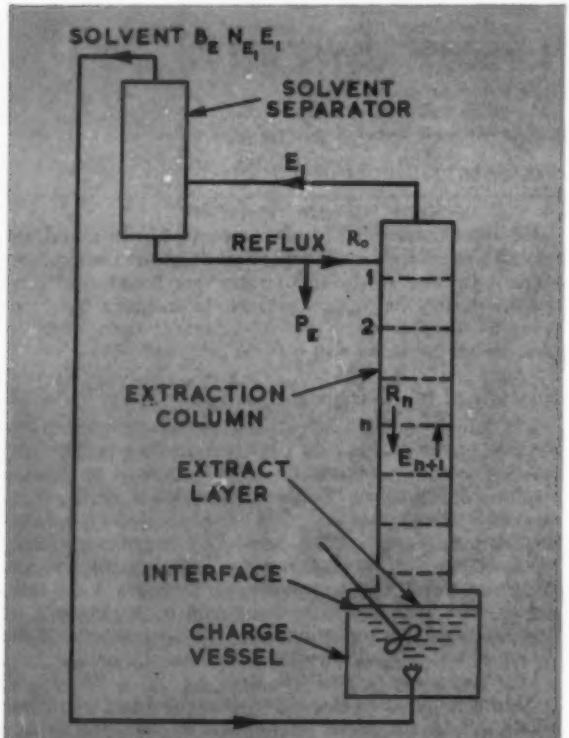

Fig. 5. Batch solvent extraction process for treating a charge of liquid with a less dense solvent.

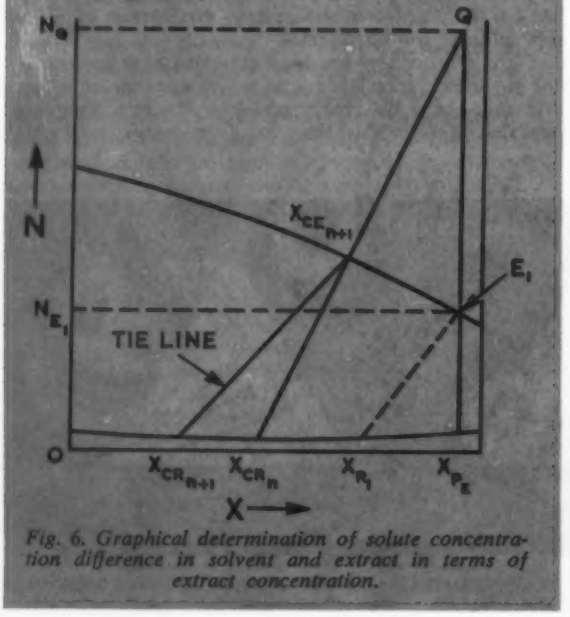

Fig. 6. Graphical determination of solute concentration difference in solvent and extract in terms of extract concentration.

or

$$-\frac{dP}{R} = \frac{dR}{R} = \frac{dX_{CR}}{X_{CE} - X_{CR}} \quad \ldots.(5)$$

and

$$\text{Log}_e \frac{R_o}{R_f} = \int_{R_f}^{R_o} \frac{dR}{R} = \int_{X_{CR}}^{X_{CE}} \frac{dX_{CR}}{(X_{CE} - X_{CR})} \quad \ldots.(6)$$

Equation (6) is similar to Smoker and Rose's[5] equation for batch rectification. In order to integrate Equation (6) the relationship between X_{CE} and X_{CR} must be known, and assuming that the rate of change of hold-up of a component on the plates, and in the solvent separator is negligible, a material balance on a solvent-free basis over the solvent separator is:

$$E_1 = P_E + R_o \quad \ldots.(7)$$

and a solvent balance is:

$$B_E = N_{E_1}.E_1 \quad \ldots.(8)$$

Now the net flow towards the top of the column

$$= Q \text{ (say) or } E_1 - R_o = P_E \quad \ldots.(9)$$

$$\text{and } N_Q = \frac{B_E}{P_E} \quad \ldots.(10)$$

$$\text{also } X_{PE} = X_{CE} = X_Q \quad \ldots.(11)$$

where N_Q = lb. of solvent per lb. of solvent-free liquor.

Equations (10) and (11) give the co-ordinates of Q on a solvent-free plot, as shown on Fig. 6. Furthermore, a solvent-free basis material-balance between the nth plate and solvent separator shows that $E_{n+1} = P_E + R_n$ ....(12)

or the net flow is $= E_{n+1} - R_n = P_E = Q$ ....(13)

Thus lines radiating from the point (N_Q, X_{PE}) intersect the equilibrium curve of Fig. 6 at points corresponding to extract and raffinate from adjacent stages. Equations (7) to (13) are identical to those used in a continuously-operated extraction, but they can be applied to determine the relationship between $X_{CE} - X_{CR}$ at any instant, and by applying them repeatedly on a plot such as Fig. 6 the value of $(X_{CE} - X_{CR})$ can be obtained as a function of X_{CR}.

As already stated a batch multi-stage extraction can be operated with the reflux ratio constant, or with variable reflux ratio and it is now proposed to apply Equation (6) to each of these methods of operation.

Constant Reflux Ratio

In any text on liquid-liquid extraction it will be shown that for a continuously operated counter-current extraction process the

$$\textit{External reflux ratio } \frac{R_o}{P_E} = \frac{\text{Line } Q\ E_1}{\text{Line } E_1 X_{PE}} = \frac{N_Q - N_{E_1}}{N_{E_1}} \quad \ldots.(14)$$

Equation (14) can be used in a multi-stage batch extraction because it applies equally well in this case, and for such a unit having, say five ideal stages and which is to operate with a fixed reflux ratio, the relation between X_{CE} and X_{CR} can be obtained as follows: Choose a value of X_{PE_1}. From the fixed reflux ratio, Q_1 is located with co-ordinates (X_{PE_1}, N_{Q_1}) Once X_{PE_1} is selected, E_1 is fixed and so is N_{E_1}. By Equation (14) and the fixed reflux ratio, N_{Q_1} is evaluated. Having located Q_1 five ideal stages are stepped off as in the manner for a continuous counter-current extraction and illustrated in Fig. 7. This establishes X_{CR_1}; and if its value is below X_F the feed composition, the chosen value of X_{PE_1} is satisfactory, otherwise a new value of X_{PE} is chosen and the process repeated to locate a new value of X_{CR_1}. As the extraction proceeds so the purity of the product decreases. Therefore a second lower value of X_{PE} is chosen, i.e. X_{PE_2} which gives N_{E_2} and from the fixed reflux ratio N_{Q_2} is calculated. The co-ordinates of Q_2 are thus obtained, and by stepping off five ideal stages

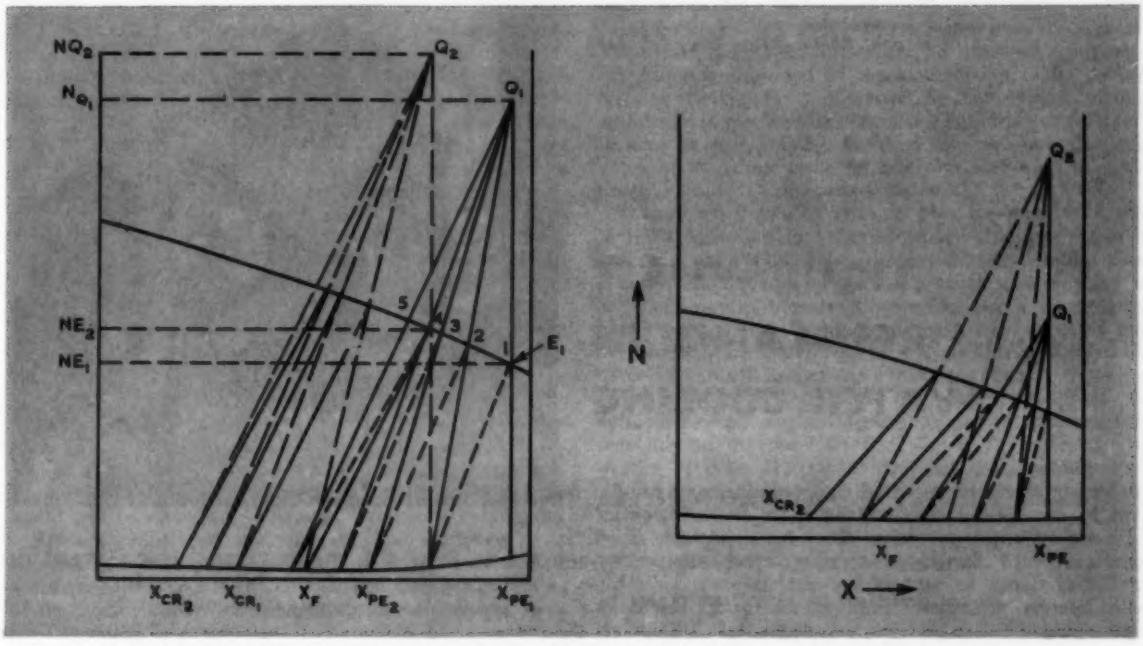

Fig. 7, left, Fig. 8, right: Alternative methods for calculating multi-stage batch solvent-extraction processes. Fig. 7. Method analogous to continuous counter-current extraction operating with a fixed reflux ratio. The example shows five ideal stages are stepped off. Fig. 8. Method based on continual adjustment of reflux ratio, also based on assuming five ideal stages.

the corresponding raffinate composition is determined, i.e. X_{CR_2}. This is shown in Fig. 7 where it will be seen that N_{Q_2} is greater than N_{Q_1}. This is in consequence of the reflux ratio and not the reflux being fixed. By repeating this procedure a number of values of $(X_{CE} - X_{CR})$ *v* X_{CR} will be obtained and by plotting $\frac{1}{X_{CE} - X_{CR}}$ *v* X_{CR} Equation (6) can be graphically integrated to obtain R_f, or X_{CE} of the bulk extract product. The method of calculation will be demonstrated in example 1, to be published in part 2 of this article.

Variable Reflux Ratio

The second method of operating a multi-stage batch extraction process is to continually adjust the reflux ratio in order to obtain an extract product of a desired purity. This type of operation will now be analysed.

If F = lb. of initial charge, then on a solvent-free basis, an overall material balance is; $F = E + R$ ....(15)
where E = lb. extract
and R = lb. raffinate.

Furthermore a solute C balance is:

$$FX_F = EX_{PE} + RX_{CR} \quad \ldots.(16)$$

Let G lb. of solvent-free extract pass through the column during the whole extraction. This will be related to the amount of extract product and reflux returned, and in a differential time interval

$$dG = dE + dO = dE + \frac{dO}{dG}.\ dG = dE + \left(\frac{R}{R+1}\right) dG \quad \ldots.(17)$$

where O = lb. reflux

and R = reflux ratio $= \frac{N_Q - N_E}{N_E}$

$$\text{From (17) } G = \int_o^G dG = \int_o^E \frac{dE}{1 - R/(R+1)} \quad \ldots.(18)$$

and from Equations (15) and (16) the weight of solvent-free extract E and, therefore, dE can be obtained.

$$\text{Thus } E = \frac{F(X_F - X_{CR})}{(X_{PE} - X_{CR})} \quad \ldots.(19)$$

$$\text{and } dE = \frac{F(X_F - X_{CE})}{(X_{PE} - X_{CR})^2} \quad \ldots.(20)$$

which, on substituting in Equation (18) gives

$$G = F(X_{CE} - X_F) \int_{X_{CR_f}}^{X_F} \frac{R+1}{(X_{PE} - X_{CR})^2} \quad \ldots.(21)$$

which is similar to Bogart's[6] equation for batch distillation.

The values of $(X_{CE} - X_{CR})$ corresponding to various values of X_{CR} are obtained graphically in a similar manner to that employed in the case of constant reflux ratio, with the modification that X_{PE} is fixed and the reflux ratio is varied. This is demonstrated on Fig. 8 where X_{PE} is the desired extract product composition, and assuming again that the column possesses five ideal stages, a reflux ratio is found by trial that will give X_F five ideal stages below X_{PE}. This is the initial reflux ratio and is illustrated on Fig. 8. As the extraction proceeds the reflux ratio is increased and Q_2 will be located above Q_1 on the perpendicular from X_{PE}. Five stages are stepped off to give X_{CR_2} and thus to obtain $(X_{PE} - X_{CR})$. This procedure is repeated a number of times and

$$\left[\frac{R+1}{(X_{PE} - X_{CR})^2}\right]$$

so evaluated is plotted versus X_{CR} to graphically integrate Equation (21) to obtain G.

From the flow rate, for the type of column employed, the time of extraction can be calculated. This method of operation will be demonstrated by example 2, to be published next month in part 2 of this article.

(To be continued)

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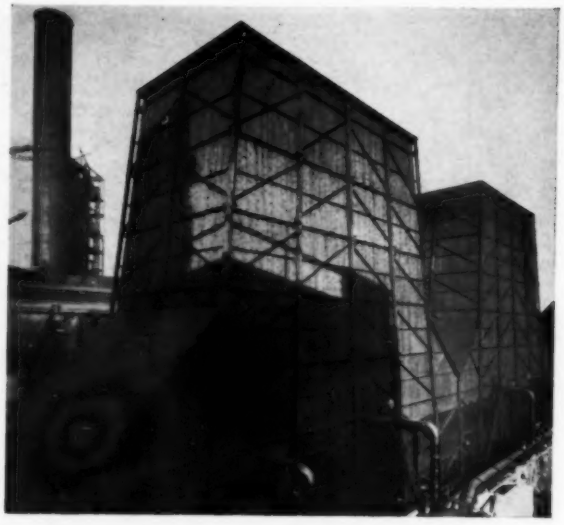

Fig. 1. A chimney-type water cooler of all-timber construction with a capacity of 610,000 gph. Photo: Visco Eng. Co. Ltd.

LIQUID-PHASE RESISTANCE IN WATER COOLING

by J. JACKSON, B.Sc.

A discussion of the significance of the liquid film heat- and mass-transfer properties in cooling towers

IN practice, the design of water-cooling towers seems almost invariably to be based on the assumption that the resistance to heat transfer of the liquid phase can be neglected.[1] This means that, because the thermal conductivity of water is so high, the temperature gradient from the bulk of the water to the interface is negligible for the heat-transfer rates encountered in practice. In other words, the bulk-water temperature and the interface temperature can be taken as being approximately equal. Evidence has been presented, however, by McADAMS *et al*[2], that this assumption is incorrect and that the liquid-phase resistance is appreciable. A design method for water-cooling towers has been worked out on this basis[3] and has been reproduced, for example, in a recent text-book on chemical engineering[4] in which, however, it is stated that it can be assumed, as a first approximation, that the entire resistance to heat transfer lies within the gas phase. It is of interest, therefore, that in a Soviet treatise on water cooling recently published,[5] one of the basic assumptions of the theoretical treatment is that at any given cross-section of the cooling tower the temperature of the water at the air/water interface can be taken as being equal to the mean-water temperature, i.e., the liquid-phase resistance can be neglected. It is further stated that this assumption can be regarded as adequately confirmed, both by experiment and by calculation. In support of this, a paper by BERMAN is quoted[6] in which the conclusions reached by McADAMS are criticised in detail and, it is claimed, are shown to be unjustified. In view of the continuing interest in this and the continuing uncertainty in the design of water-cooling towers, British chemical engineers may find a summary of BERMAN's conclusions of value.

It will be recalled that McADAMS's experiments were carried out with counter-current flow of the air and water, and with a ring packing. In a first series of experiments, conditions were "adiabatic", in that all the heat given up by the water to the air was lost entirely as a result of evaporation. The temperature of the water, which was much lower than that of the air, remained unchanged; thus any possible liquid-phase resistance was eliminated. In the second series of experiments, the same apparatus was used for the cooling or heating of water. For this second series of experiments, the volume coefficients of mass transfer, calculated on the basis of the mean water temperature, were found to be 30 to 60% less than those found in the first series. It was then assumed by McADAMS that this difference could be entirely explained by the existence of a liquid-phase resistance to heat transfer, and values of the volume heat-transfer coefficient for the liquid phase were calculated.

The method of calculation used is important, since this is criticised by BERMAN. The volume mass-transfer coefficients, β_{xv} (using BERMAN's symbols), for the second series of experiments were, in fact, calculated from a correlation derived from the results of the first series:

$$\beta_{xv} = a\ g_g^{\,b}\ g_l^{\,c} \qquad \ldots . (1)$$

where g_g = weight velocity of gas;
g_l = weight velocity of liquid;
and a, b and c are constants. The quantity I was then calculated from:

$$I = \frac{V\,\beta_{xv}}{G_g} = \frac{H\,\beta_{xv}}{g_g} \qquad \ldots . (2)$$

where V = volume of packing;
G_g = gas rate; and
H = height of packing.

It can also be shown, from the MERKEL total heat equation for water cooling,[1] that:

$$I = \int_{i_1}^{i_2} \frac{di}{i'' - i} \qquad \ldots . (3)$$

where i'' = enthalpy of saturated vapour/gas mixture at temperature of gas/liquid interface; and
i = enthalpy of bulk of vapour/gas mixture.

Equation (3) was solved graphically, assuming that the angle θ made by the tie-lines on the enthalpy/temperature diagram (see Fig. 2) was constant. A value of θ was then chosen so as to obtain agreement between the values of I calculated from Equations (2) and (3). Since the value of θ is equal to the ratio of the heat-transfer coefficient,

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α_{lv}, for the liquid phase to the mass-transfer coefficient, this assumption of a constant value of θ implies also that α_{lv} is a constant.

BERMAN criticises the assumptions underlying these calculations, which are:

(i) That the difference between the mass-transfer coefficients for the two different régimes where the only common factor was that the weight velocities, g_g and g_l were the same, can be explained entirely by the liquid-phase resistance.

(ii) That the empirical correlation for the mass-transfer coefficient obtained from the first series of experiments can be extrapolated to apply to the conditions of the second.

In addition, BERMAN comments that the assumption that α_{lv} is a constant is also unjustified. Even with pure streamline flow of the liquid, without mixing, in the initial stages of the process there will be no difference between the interfacial and bulk temperatures of the liquid. Consequently, α_{lv} must initially have a value of infinity though it will, of course, eventually attain a finite value. This assumption of a constant α_{lv} also ignores that the liquid will be mixed in its passage through the apparatus.

BERMAN points out that the assumed existence of a significant liquid-phase resistance implies the existence of a difference between the interfacial and bulk temperatures of the liquid, but that these temperature differences were not calculated by MCADAMS. It is possible, however, from the experimental data given by MCADAMS, to calculate the mean value of this temperature difference $\triangle t_1$ from:

$$\triangle t_1 = \frac{q_v}{\alpha_{lv}}$$

where q_v = mean volume heat flux.
The value of q_v is given by:

$$q_v = \frac{G_l\ C_l\ (t_1 - t_2)}{V}$$

G_l = liquid rate;
C_l = specific heat of water;
t_1 = inlet water temperature; and
t_2 = exit water temperature.

As an example, the necessary data for one of MCADAMS's water-cooling experiments are set out below. BERMAN also gives figures derived from the results of similar experiments carried out by YOSHIDA and TANAKA.[7]

Weight velocities:	
Water (g_l)	3420 kg/m² hr.
Air (g_g)	1690 kg/m² hr.
Water temperatures:	
Inlet (t_1)	57.8°C.
Exit (t_2)	37.2°C.
Inlet air temperatures:	
Dry-bulb	43.9°C.
Wet-bulb	20.1°C.
Exit air wet-bulb temperature	46.2°C.
Liquid-phase volume heat-transfer coefficient (α_{lv}) ...	22.720 k. cal./m³ hr °C.
Mean volume heat flux (q_v)	231.0 k.cal./m³ hr 10^3
Mean temperature difference of water	10.2°C.

If the value of α_{lv} is assumed to be constant over the entire heat-transfer surface, the $\triangle t_1$ value must change. In fact, it must attain a maximum local value exceeding the mean value given above for the water inlet. This, however, is contrary to the physical picture of the process. Thus it follows that for a cooling range of 13-20°C the mean temperature difference between the bulk of the water and the water surface is in the range 5 to 10°C, while the local value of this temperature difference may be as much as 8-15°C. This seems highly improbable in water cooling where the average heat flux does not exceed 350-400 k.cal./m.² hr, and where, in film-type equipment, the water is subjected to repeated mixing in its passage through the apparatus. Moreover, if this repeated mixing, with its consequent reduction of the liquid-phase resistance to zero at each mixing, is taken into account, the local value of $\triangle t_1$ must be significantly greater even than the range 8 to 15°C mentioned above.

It has been shown by PRÜGER[8] that, for the evaporation at 100°C of water in a heated vessel with heat fluxes in the range 2200-4300 k.cal./m.² hr, the temperature drop across the boundary layer of the water was only 2.5 to 4.0°C. In view of the conditions under which these experiments were carried out, it would have been expected that the temperature differences found by MCADAMS would have been much smaller than those found by PRÜGER.

The work of HÄUSZLER on the temperature profile on both sides of an evaporating surface[9], which appeared subsequently to the publication of BERMAN's paper, is also worthy of note. HÄUSZLER measured these profiles over a wide range of conditions for water in a vessel, over the surface of which air at different velocities was passed, heat being either supplied to or withdrawn from the water by means of a thermostat as required. The maximum difference between the temperature of the bulk of the water and that of the air/water interface was found to be about 3.2°C. HÄUSZLER also reviewed earlier measurements of this type due to HEIDRICH[10] and LEVEN[11] (though he seems to have been unaware of the work of PRÜGER) and these workers reported maximum temperature differences of about 5°C and 4°C respectively. Further support is thus provided for BERMAN's assertion that the temperature differences presupposed by MCADAMS are so large as to be extremely improbable.

Thus the difference between the mass-transfer coefficients found in MCADAMS's second series of experiments, as compared with those in the first, still requires explana-

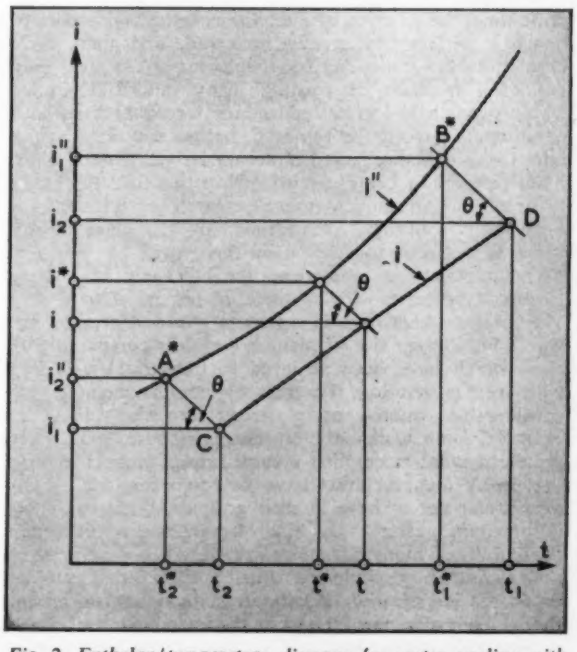

*Fig. 2. Enthalpy/temperature diagram for water cooling with tie-lines at constant angle θ to the horizontal. The tie-lines (A*C and B*D) are the lines connecting the corresponding points on the equilibrium and operating lines (A*B* and CD respectively).*

tion. This explanation can be found only by conducting suitable experiments. It is pointed out by BERMAN, however, that for equal values of the air velocity, g_0, the conditions prevailing in the two series of experiments were quite different. Thus in the "adiabatic" series, for a water temperature of 35 to 40°C, the inlet air temperature was in the range 100 to 150°C, while in the second series the air temperature was only 30 to 40°C. This difference would require for the correct calculation of β_{xv} in the two series of experiments, a correlation of the experimental data in the form of a general equation including such physical quantities as the viscosity and the diffusion coefficient, which vary with temperature; it would also allow for the effect of the transfer of matter in a direction at right angles to the interface on the velocity distribution and the partial vapour pressure. Account must also be taken of the possible variation of the specific surface of the liquid F_{sp} ($m.^2/m.^3$) on which the volume mass-transfer coefficient depends, according to the relation: $\beta_{xv} = \beta_x F_{sp}$ (kg./m.^{2} hr) where $\beta_x =$ area mass-transfer coefficient (kg./m.^{2} hr).

Furthermore, the greater part of MCADAMS's experiments were carried out at water loadings less than 5 m.^{3}/m.^{2} hr, and the lowest water loadings used (0.9-3.5 m.^{3}/m.^{2} hr) corresponded to the greatest reduction in the value of β_{xv}, as between the two series of experiments. For such low water loadings, with random ring packings, the fraction of the packing surface wetted must be relatively small, and any change in the air rate might be expected to produce a large change in F_{sp}. The experimental data in this field are insufficient, however, to test this supposition.[12].

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Water Supply and Waste Water Disposal

by B. A. SOUTHGATE, C.B.E., D.Sc.

STARTING with the observation that sewage can be purified by allowing it to percolate through the soil or (given enough time) by discharging it to a river, treatment plants of various kinds have been developed, largely during the past 50 years, in which sewage can be purified effectively without offence and at comparatively small cost. The modern activated-sludge plant for example is compact, virtually odourless, almost entirely mechanised in its operation, and capable, if necessary, of producing an effluent reasonably resembling water—indeed of better quality than the water of some industrial rivers. At the same time, the practice of discharging industrial waters to domestic sewers has greatly increased, and there have been notable improvements in physical, chemical and biological methods of treating many industrial liquors whose strength has to be reduced, or from which noxious constituents have to be removed, before they can be put into a sewer or discharged direct to a river. Nevertheless, more research is being carried out in this field than ever before, and particularly more research by industry or financed by industry. What, then, are the chief objects which it is hoped to achieve by this work?

One certainly is to increase the efficiency of existing treatment processes—for example, of biological treatment. The rate at which organic matter is removed at a sewage works for a given size of plant is very low compared with rates which have been achieved in industrial fermenters with intense aeration. To treat by present methods any considerable volume of a strong organic waste, for example, from a cannery or slaughter-house, might well require a plant resembling a rural sewage works: a thing that many manufacturers have no room for, and in any case prefer not to have in their grounds. What is wanted is something nearer to the kind of plant one would expect to find in a modern factory, small, of high efficiency, under cover, properly instrumented and, as far as possible, automatic in operation. Again, an industrialist considering the building of a new factory or the introduction of a new process of manufacture often wants to know before going too far what the probable effect of an effluent of a given quality will be on the stream or estuary to which it would be discharged, and at present any estimate which may be made is largely a matter of guess-work.

The advances which have so far been made in the field of pollution prevention have come about largely as the result of empirical experiments. No doubt this line of attack will still yield dividends, but there is a widespread feeling that if massive advances are to be achieved the reactions on which the various processes of treatment of wastes and of purification of natural waters depend should be examined in a much more fundamental way. Some research of this kind has, of course, been done, particularly in this country and America, for a good many years past and there has been an obvious increase in amount during the last three or four years. In America one of the most enthusiastic members of this school, who has himself contributed a great deal to the development of the subject, is DR. G. M. FAIR, Professor of Engineering and Sanitary Engineering at Harvard University. With DR. J. C. GEYER he has now published a most interesting book* in which the principles on which water supply and waste water disposal are based are set out. These, so far as is possible, are in mathematical form and are used, with many examples, as a basis for the calculation of the design of treatment plants and the prediction of the results to be expected when effluents are discharged to streams. The authors, in their preface, acknowledge that the degree of empiricism in these calculations still remains high, and indeed this is obvious if the performance of a treatment plant, for which the results happen to be known from observation, is compared with that expected from the calculations suggested; or if the known course of self-purification in a river is compared with the predicted course. Nevertheless, the subject is now clearly developing on the right lines; the publication of FAIR and GEYER is an important event recording the progress so far made. If a second edition appears, say, in five years time, the authors should be able to report a noticeable reduction in the extent to which they employ empiricism in their calculations.

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* "Elements of Water Supply and Waste-water Disposal." G. M. Fair and J. C. Geyer. John Wiley & Sons Inc., New York; Chapman & Hall Ltd., London, 1958. 72s. (Based on the larger work, "Water Supply and Waste Water Disposal", by G. M. Fair and J. C. Geyer. John Wiley & Sons Inc., New York; Chapman & Hall Ltd., London, 1954.)

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CONTRIBUTIONS TO THE STUDY OF DIFFERENTIAL ABSORPTION

A method illustrated by worked examples is proposed for solving multi-stage differential mass-transfer problems

by Dr. Ir. I. V. ROBU

IN large-scale industrial operations absorption counter-current is generally more advantageous than co-current operation. The methods of estimating the dimensions of equipment required for counter-current processes have been described in great detail in a number of treatises on chemical engineering.

It is not invariably the case that counter-current operation is the best method to employ; sometimes the advantages may lie with the co-current method, or sometimes it may be better to have the liquid phase stationary. This latter could be applied, for example, to the case of a carrier gas containing a soluble component of relatively low solubility and when the quantity of gas to be handled is small. The apparatus employed would then consist of a number of vessels through which the gas would be passed and the liquid-phase absorbent would be contained without movement in the vessels.

When this method is used industrially the gas is introduced into the mass of absorbing liquid in a finely divided state. The large surface of contact thus produced between the phases ensures good mass transfer and the stream of gas bubbles maintains the absorbing liquid in a turbulent state so that the resistance of the liquid film is kept small. This method of absorption is therefore applicable to those cases in which the resistance of the film of liquid is the controlling factor in the absorption process. It can be shown[1, 2] that by passing the gas through several absorbers connected in series and by periodic removal from the system of the enriched solution, then such a process approaches in effectiveness those operated counter-currentwise.

The quantitative behaviour of absorption systems employing one or a number of vessels in which the liquid is not transferred will now be considered. As in the differential extraction, the continuous introduction of a gaseous phase carrying the soluble component leads to the establishment of equilibrium between phases at any time during the process, i.e., the soluble component is redistributed between gas and liquid phases according to the equilibrium conditions specific to the given system. This process likewise is differential and the concentration of the component in each phase changes in differential manner in the course of the process.

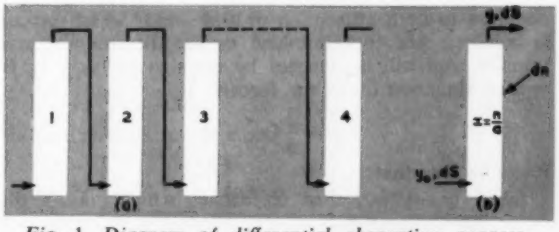

Fig. 1. Diagram of differential absorption process. Solution from a vessel is replenished when close to equilibrium saturation of interior gas.

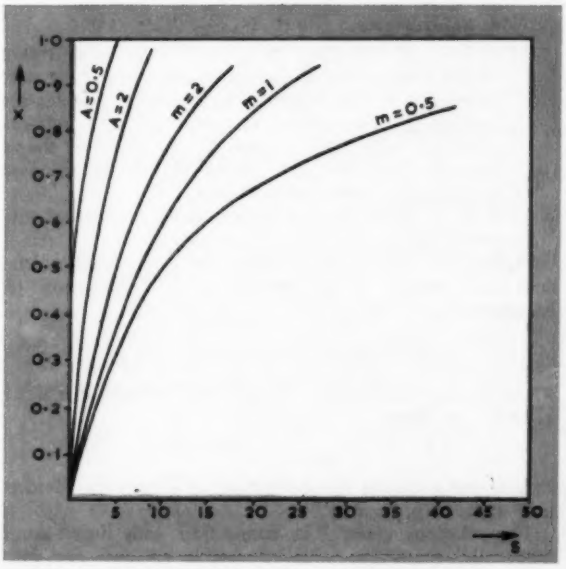

Fig. 2. Variation of carrier gas composition with solution composition in a single-stage absorption without removal of liquid phase.

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The Derivation of the Fundamental Relationships in Differential Absorption

S = amount of mobile phase, carrying the component (kg, moles, volume of gas);

a = amount of stationary phase (absorbent) (kg, moles, volume of liquid);

y_o = concentration of the component in the gas phase on entering the absorber (kg/kg, mole/mole, vol/vol);

y = concentration of the component in the gas phase on leaving the absorber (kg/kg, mole/mole, vol/vol);

n = amount of component in the stationary phase (kg, moles, volume); and

$x = n/a$ = concentration of the component in the stationary phase (kg/kg, mole/mole, vol/vol).

By a differential material balance on the component at any time we have (Fig. 1b):

$$y_o\,dS = y\,.\,dS + dn \qquad \ldots.(1)$$

hence $(y_o - y)\,dS = dn$

but $x = n/a$

therefore $dn = a\,.\,dx \qquad \ldots.(2)$

From Equations (1) and (2) we obtain the fundamental differential relationship:

$$(y_o - y)\,dS = a\,.\,dx \qquad \ldots.(3)$$

Equation (3) is the basic expression for material balance in any differential process of mass transfer between a mobile phase and a stationary phase and will therefore be common to both absorption or extraction; which process is involved will be determined by the direction of mass transfer, and will be denoted by the sign of $(y_o - y)$. By writing Equation (3) in the form

$$\frac{dx}{dS} = \frac{1}{a}(y_o - y) \qquad \ldots.(4)$$

it can be seen that:

(a) if $(y_o - y) > 0$, then $dx/dS > 0$, which means that the concentration of the component increases with increasing S. This applies to absorption, washing and adsorption processes, and the relation $x = f(s)$ will have the shape of the curves in Fig. 2, because $(y_o - y)$ and therefore dx/dS decreases with increasing S;

(b) if $(y_o - y) < 0$, then $dx/dS < 0$; the concentration of the component in the stationary phase falls with increasing S. The processes to which this applies are extraction, desorption, elution, and the relation $x = f(S)$ will have curves of the reverse shape, because $(y_o - y)$ and, therefore, dx/dS increase algebraically with increase in S.

(c) if $y_o = y$ and $dx/dS = 0$ there is no transfer of substance from one phase to another.

In verifying case (b), we observe that if the mobile phase does not contain a component ($y_o = 0$) Equation (3) becomes:

$$-y\,dS = a\,dx;\quad -dS = a\frac{dx}{y} = a\frac{dx}{f(x)}$$

while, if $f(x) = Kx$, after integration between the limits x_o and x we have

$$x = x_o\,e^{\frac{-KS}{a}}$$

This is the equation for extraction or differential desorption deduced previously.[1]

The relations given[1, 2] in connection with liquid-liquid differential extraction with immiscible solvents are valid also for desorption and elution processes carried out differentially; the difference between these processes lies only in the physical state of the phases; gas-liquid or gas-solid in desorption and liquid-solid for elution.

In the case of elution, adsorption and gas-solid desorption, the stationary phase is fixed; this fact requires use of the H.E.T.P. concept.

Case (a) in which $y_o - y > 0$ refers not only to absorption (gas-liquid) but also to washing (liquid-liquid) and to adsorption (liquid-solid gas-solid) processes.

If the repartition of the component in equilibrium between the mobile phase and the stationary phase is of the general form $y = f(x)$, and assuming that equilibrium is attained in the absorption vessel at any time of the process, Equation (3) becomes:

$$[y_o - f(x)]\,dS = a\,.\,dx,$$

which, after separation of the variables and integration between 0 and S, and between 0 and x leads to the relationship:

$$-\int_S^0 dS = a\int_0^x \frac{dx}{f(x) - y_o},\ \text{and}\ S = a\int_0^x \frac{dx}{y_o - f(x)} \qquad \ldots.(4)$$

This relation allows calculation of the concentration, x, of the solution in the absorber and, therefore, also that y, the concentration of the gas, leaving the absorber as a function of the quantity "S" of gas (the inert component). If $y = f(x)$ has no analytical expression, or if this cannot be integrated analytically, then Equation (4) must be solved by the usual graphical integration.

In a few cases and for practically all dilute solutions, i.e., where Henry's Law holds, the equilibrium relation may be expressed by $y = Kx$.

Substituting in Equation (4) we obtain for the case where Henry's Law holds:

$$S = a\int_0^x \frac{dx}{y_o - Kx} = \frac{a}{K}\int_0^x \frac{dx}{\frac{y_o}{K} - x}$$

From this

$$-\frac{KS}{a} = ln\left(1 - \frac{K}{y_o}x\right)\ \text{and}\ 1 - \frac{K}{y_o}\,.\,x = e^{\frac{-KS}{a}}$$

and $$x = \frac{y_o}{K}\left(1 - e^{\frac{-KS}{a}}\right) \qquad \ldots.(5)$$

From the Freundlich equation $y = Kx^m$, Equation (4) becomes:

$$S = a\int_0^x \frac{dx}{y_o - Kx^m} \qquad \ldots.(6)$$

If the Langmuir Law applies:

i.e., $y = K\frac{x}{A + x}$ where A is a constant, then (4) becomes

$$S = a\int_0^x \frac{dx}{y_o - \frac{Kx}{A + x}}$$

which on integration gives the expression:

$$S = \frac{a}{y_o - K}\left[x - \frac{AK}{y_o - K}\,ln\left(1 + \frac{y_o - K}{A\,y_o}x\right)\right]_0^x \qquad \ldots.(7)$$

The general form of the curves given by Equations (6) and (7) is shown in Fig 2. For $m = \frac{1}{2}$, 1, 2, Equation (6) can be integrated directly, giving:

$m = \frac{1}{2}$,

$$S = \frac{2a}{K^2}\left[y_o\,ln\frac{y_o}{y_o - Kx^{\frac{1}{2}}} - Kx^{\frac{1}{2}}\right]$$

$m = 1$

$$S = \frac{a}{K}\,ln\frac{y_o}{y_o - Kx},\ \text{or}\ x = \frac{y_o}{K}\left(1 - e^{\frac{-KS}{a}}\right)$$

$m = 2$

$$S = \frac{a}{2\sqrt{y_o K}}\,ln\frac{\sqrt{y_o} + x\sqrt{K}}{\sqrt{y_o} - x\sqrt{K}}\ \text{or}$$

$$x = \sqrt{\frac{y_o}{K}} \cdot \left(\frac{e^{\frac{2s\sqrt{y_o K}}{a}} - 1}{e^{\frac{2s\sqrt{y_o K}}{a}} + 1} \right)$$

These expressions are illustrated for $y_o = K = 1$ and $a = 10$ in Fig. 2. In Fig. 2 are given also the curves corresponding to Equation (7) for $y_o = 2$, $k = 1$, $A = 0.5$ and $A = 2$ respectively. The curves of Equation (6) are asymptotic for $x = \left(\frac{y_o}{K}\right)^{\frac{1}{2}}$ and $x = \frac{y_o}{K}$.

The efficiency of the absorber can be evaluated by the same criteria as for extraction. If we denote by E the efficiency of the apparatus, then:

$$E = \frac{\text{quantity absorbed}}{\text{quantity that can be absorbed theoretically}}, \text{ i.e.}$$

if $y = Kx$

$$E = \frac{a_{\,x\ \text{actual}}}{a_{\,x\ \text{theoretical}}} = \frac{x_a}{x_t} = \frac{x_a}{\frac{y_o}{K}\left(1 - e^{\frac{-KS}{a}}\right)}$$

If $y = f(x)$ is not amenable to analytical integration, then the efficiency of the absorption apparatus may be estimated by graphic integration by plotting the expression $\frac{1}{y_o - f(x)}$ against x, and finding x_t for a given S and calculating the term $x_a/x_t = E$.

Successive Absorption

If the variation of the concentration of the absorbed component (Fig. 2) is followed, it is noticeable, especially in the asymptotic curves represented by Equation (6) at the beginning of the process, i.e., for small values of S, that the quantity absorbed is large but as the process proceeds the amount absorbed decreases (large values of S). This means that the inert gas will leave the absorber more and more rich in the soluble component as the process proceeds, and in order to remove the remainder another absorber is used. Once this absorber approaches equilibrium saturation conditions, the gas will have to be passed into a third absorber and so on. One can therefore visualise "successive absorption" (Fig. 1) as an absorption system consisting of a number of absorbers in (or series) operation with a fresh absorber to replace a saturated one. The system is therefore analogous to differential extraction and has the advantages peculiar to this system. By having a number of "p" of absorbers in use and one or more absorbers for replacing exhausted ones it is possible to make this type of absorption continuous. At the same time, a reduced quantity of absorbent may be used because the solution from each absorber is removed from circulation when nearly saturated with the soluble component.

It is desired to discover the relation between the concentration of the mobile phase (y_p) and the stationary (x_p) in the absorber "p" as a function of the amount of gas S carrying a soluble component, i.e., the functions $y_p = f(S, p)$ or $x_p = \phi(S, p)$ where the equilibrium relation is $y = Kx$.

If "p" absorbers are connected in series and if "a" is the amount of pure absorbent in each absorber, then since the carrier gas changes its composition continuously with time as it passes from vessel to vessel a differential material balance for the component gives Equation (1).

In this expression y is a variable whose value is determined by S and the position of the absorber in the system. For two adjacent absorbers ("$i-1$" and "i") this equation becomes

$$y_{i-1}\, dS = y_i\, dS + dn_i \qquad \ldots . (8)$$

but $\frac{n_1}{a} = x_l$ while $y_l = Kx_l$

therefore $n_i = a\, x_i = \frac{a}{K} y_i$ and $dn_i = \frac{a}{K} dy_i \ldots . (9)$

From Equations (8) and (9) we obtain:

$$y_{i-1}\, dS = y_i\, dS + \frac{a}{K} dy_i$$

i.e., $$\frac{dy_i}{dS} + \frac{K}{a} y_i = \frac{K}{a} y_{i-1} \qquad \ldots (10)$$

This is the basic equation for successive differential absorption and it permits the calculation of the conditions at any point in the system after the passage of any period of time. This equation may be solved as follows:

Absorber 1

For "i" = 1, Equation (10) becomes:

$$\frac{dy_1}{dS} + \frac{K}{a} y_1 = \frac{K}{a} y_o \qquad \ldots (11)$$

In this equation y_o is constant, hence:

$$dS = \frac{a}{K} \cdot \frac{dy_1}{y_o - y_1}$$

Integrating between the limits $S = 0$ and $S = S$ or respectively between the limits y and 0 (for $S = 0$, $y_1 = 0$, since in the vessel there is only pure solvent and therefore $x_1 = 0$; similarly if $y_1 = Kx_1$, then $y_1 = 0$):

$$S \int_S^x = -\frac{a}{K}\Big[ln\,(y_o - y) \Big]_{y_1}^{a}\ ;\ S = \frac{a}{K}\, ln\, \frac{y_o}{y_o - y_1}$$

which reduces to

$$y_1 = y_o \left[1 - e^{\frac{-KS}{a}}\right] \qquad \ldots (12)$$

Absorber 2

For "i" = 2, Equation (10) becomes:

$$\frac{dy_2}{dS} + \frac{K}{a} y_2 = \frac{K}{a} y_1 \text{ and from Equation (12)}$$

$$\frac{dy_2}{dS} + \frac{K}{a} y_2 = \frac{K}{a} y_o \left[1 - e^{\frac{-KS}{a}}\right]$$

This equation, being linear and of the first order, can be solved by conventional methods to give:

$$y_2 e^{\frac{-KS}{a}} = \frac{y_o K}{a} \int \left(e^{\frac{-KS}{a}} - 1 \right) dS + C$$

and $$y_2 e^{\frac{-KS}{a}} = y_o e^{\frac{-KS}{a}} - y_o \cdot \frac{KS}{a} + C$$

In order to determine the constant of integration, we note that for $S = 0$ $C = y_2 - y_o$, while $y_2 = 0$, since $y_2 = Kx_2$ and $x_2 = 0$ for $S = 0$. Therefore $C = y_o$; by substitution in the equation above we obtain:

$$y_2 = y_o \left[1 - \frac{KS}{a} e^{\frac{-KS}{a}} - e^{\frac{-KS}{a}}\right] \text{ or}$$

$$y_2 = y_o \left[1 - e^{\frac{-KS}{a}} \left(1 + \frac{KS}{a}\right)\right] \qquad \ldots (13)$$

Absorber 3

For "i" = 3, Equation (10) gives:

$$\frac{dy_3}{dS} + \frac{K}{a} y_3 = \frac{K}{a} y_2$$

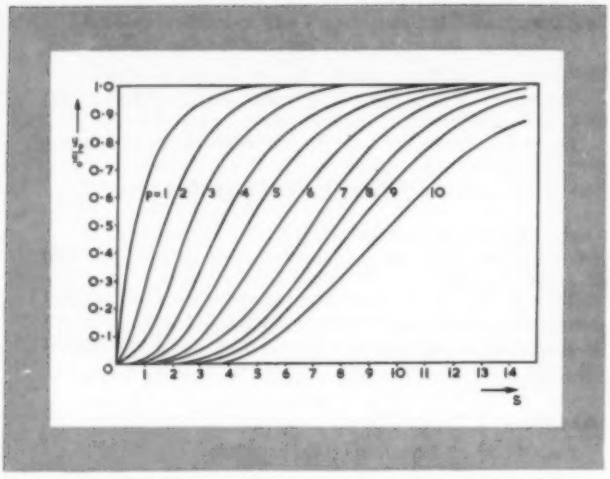


Fig. 3. Graphical solution of equation giving inert gas composition at various stages of a multi-stage differential absorption process.

Substituting for y_2 from Equation (13):

$$\frac{dy_3}{dS} + \frac{K}{a} y_3 = \frac{K}{a} y_o \left[1 - e^{\frac{-KS}{a}} \left(1 + \frac{KS}{a}\right)\right]$$

This equation also is a first-order linear equation and is solved as before to give:

$$y_3 = y_o \left[1 - e^{\frac{-KS}{a}} \left(1 + \frac{KS}{a} + \left(\frac{KS}{a}\right)^2 \frac{1}{2!}\right)\right] \quad \ldots (14)$$

Absorber 4

For "i" = 4, Equation (10) will be:

$$\frac{dy_4}{dS} + \frac{K}{a} y_4 = \frac{K}{a} y_3$$

Combining this equation with Equation (14) we obtain:

$$\frac{dy_4}{dS} + \frac{K}{a} y_4 = \frac{K}{a} y_o \left[1 - e^{\frac{-KS}{a}} \left[1 + \frac{KS}{a} + \left(\frac{KS}{a}\right)^2 \frac{1}{2}\right]\right]$$

which, on solution, gives

$$y_4 = y_o \left[1 - e^{\frac{-KS}{a}} \left[1 + \frac{KS}{a} + \left(\frac{KS}{a}\right)^2 \frac{1}{2!} + \left(\frac{KS}{a}\right)^3 \frac{1}{3!}\right]\right]$$

Proceeding as further above, we obtain for the absorber "p":

$$y_p = y_o \left[1 - e^{\frac{-KS}{a}} \left[\frac{KS}{a} + \left(\frac{KS}{a}\right)^2 \frac{1}{2!} + \left(\frac{KS}{a}\right)^3 \frac{1}{3!} + \ldots \left(\frac{KS}{a}\right)^{p-1} \frac{1}{(p-1)!}\right]\right]$$

$$\text{or} \quad y_p = y_o \left[1 - e^{\frac{-KS}{a}} \sum_{i=o}^{p-1} \frac{\left(\frac{KS}{a}\right)^i}{i!}\right] \quad \ldots (15)$$

But $y_p = kxp$ and therefore:

$$x_p = \frac{y_o}{K} \left[1 - e^{\frac{-KS}{a}} \sum_{i=0}^{p-1} \frac{\left(\frac{KS}{a}\right)^i}{i!}\right] \quad \ldots (16)$$

The variation of y_p and x_p with S is obtained from the following:

The derivatives:

$$\frac{dy_p}{dS} = y_o \left(\frac{K}{a}\right)^p e^{\frac{-KS}{a}} \frac{S^{(p-1)}}{(p-1)!}$$

$$\frac{dx_p}{dS} = \frac{y_o}{K} \left(\frac{K}{a}\right)^p e^{\frac{-KS}{a}} \frac{S^{(p-1)}}{(p-1)!}$$

are positive, therefore the curves rise continuously. The derivatives:

$$\frac{d^2y_p}{dS^2} = -y_o \left(\frac{K}{p}\right)^p e^{\frac{-KS}{a}} \frac{S^{(p-2)}}{(p-1)!} \left(\frac{KS}{a} - (p-1)\right]$$

$$\frac{d^2x_p}{dS^2} = \frac{-y_o}{K} \left(\frac{K}{p}\right)^p e^{\frac{-KS}{a}} \frac{S^{(p-2)}}{(p-1)!} \left[\frac{KS}{a} - (p-1)\right]$$

are positive for $S < a/k\,(p-1)$, negative for $S > a/K\,(p-1)$ and cancel for $S = a/K\,(p-1)$; the corresponding curves are concave upwards for $S < a/K\,(p-1)$, concave downwards for $S > a/K\,(p-1)$ and have a point of inflexion for $S = a/K\,(p-1)$. For $p = 1$ (one absorber only) the derivatives of the second order are negative for any value of S, and therefore the curves have no point of inflexion, being concave downwards.

The curves $y = f(S, p)$ corresponding to Equation (15) are represented in Fig. 3 for $p = 1, 2, 3, \ldots 10$ and $K/a = 1$. These curves show that the first absorbers become quickly enriched of the absorbed material, and while the ones nearer the end become enriched more slowly, the higher the number denoting the position of the absorber, starting from the first one in the line, the slower the rate of enrichment.

Inspection of Equation (15) leads to the conclusion that at $p =$ const., the expression in the bracket is a uniform function of the variable $(\frac{KS}{a})$, i.e., for a given value of this dimensionless parameter the value of the function $\frac{y_p}{y_o}$ is the same irrespective of the values of K, S, a. This means that by introducing $(\frac{KS}{a})$ on the abscissa instead of S, the curves in Fig. 3 are also the graphical representations of Equation (15) for different values of p.

Equation (15) is based on the assumption that the absorbers attain theoretical equilibrium. As in differential extraction, it is possible to estimate the number of stages required for cases where the efficiency of the absorbing process is less than 1.

If the amount of pure absorbent in the entire system is V and "a" is the quantity in one absorber, then $p.a. = V$, where "p" is the theoretical number of absorbers in the system. Substituting "a" from this relationship in Equation (15), we obtain:

$$y_p = y_o \left[1 - e^{\frac{-KSp}{V}} \left[1 + \frac{KSp}{V} + \left(\frac{KSp}{V}\right)^2 \frac{1}{2!} + \left(\frac{KSp}{V}\right)^3 \frac{1}{3!} \cdots \left(\frac{KSp}{V}\right)^{p-1} \frac{1}{(p-1)!}\right]\right]$$

This equation can be used for solving the total number of vessels required if y_p is determined experimentally after the passage of a quantity S of gas through the system.

Experimental Test of Derived Equations

Both Equations (15) and (16) have been tested experimentally in the following manner. Three small vessels of same dimensions were connected together in series by overflow pipes. Each contained 400 cc of water as dynamic volume up to the overflow, while air was passed through and dispersed through the liquid by means of porous plates.

To the first vessel a 3.2% w.w. solution of acetic acid in water was continuously added at the rate of 40 cc/min. A sample of 1 cc was withdrawn per 100 cc of liquid leaving vessel 3. This simple absorption (dilution) experiment gave the results shown in Fig. 4; the curve for Equation (15) is included for comparison. The points for the curve are based upon:

$$K = 1,\ p = 3,\ a = 400,\ y_o = 3.2$$

which on substitution in Equation (15) gives:

$$y_3 = 3.2\left[1 - e^{\frac{-S}{400}}\left[1 + \frac{S}{400} + \left(\frac{S}{400}\right)^2 \frac{1}{2}\right]\right]$$

The agreement between actual and calculated results is excellent.

The following example illustrates the application of the conclusions of this article to a problem in absorption.

Example 1

A valuable solute is to be recovered from a dilute solution by adsorption on a suitable adsorbent. The solution contains 0.99% solute (by weight), and 4444 Kg of solution is passed per cycle through the adsorber of diameter 1.0 m, filled with granular adsorbent of 700 Kg/m³ bulk density. For the constant flow rate and temperature of the process it is found that the height of a theoretical transfer unit is 0.02 m. For the dilute region considered, the adsorption isotherm is a straight line with the slope of 0.1

$$\left(K = y/x = \frac{\text{Kg solute/Kg solvent}}{\text{Kg solute/Kg adsorbent}}\right).$$

Find the solute recovery if the height of the absorbent bed is 0.80 m; 1.00 m; 1.20 m.

Solution

$K = 0.1$, $\qquad a = 0.785 \,.\, 0.02 \,.\, 700 = 11\text{Kg}.$

$$S = 4444 \,.\, \frac{99.01}{100} = 4400 \text{ Kg}. \qquad y_o = \frac{4444 \,.\, 0.99}{4400 \,.\, 100} = 0.01$$

In each case the number of transfer units = 40, 50 and 60 respectively.

The amount of solute lost in the spent solution is thus given by

$$y_{p\,(\text{average})} \,.\, S = y_o \int_0^S \left[1 - e^{\frac{-KS}{a}} \sum_{i=0}^{p-1} \left(\frac{KS}{a}\right) \frac{1}{i!}\right] dS$$

and the percentage recovery is:

$$\left(1 - \frac{y_{p(\text{average})}}{y_o}\right) 100.$$

Since K, a, S, y_o and p are known, y_p (average) could be readily calculated from the above equation if it were analytically integrable. Graphical integration of this equation is also impracticable due to the tedious labour necessary for plotting the expression under the integral, since p varies from 40 to 60.

But since Equation (15) may be written:

$$\frac{y_p}{y_o} = \int_0^{\frac{KS}{a}} \frac{e^{\frac{-KS}{a}}}{(p-1)!} \left(\frac{KS}{a}\right)^{p-1} d\,\frac{KS}{a}$$

from STIRLING'S expression

$$(p-1)! = e^{-(p-1)}\,(p-1)^{p-1}\,\sqrt{2\,\pi\,(p-1)}$$

it follows that

$$\frac{y_p}{y_o} = \int_0^{\frac{KS}{a}} \frac{1}{\sqrt{2\pi(p-1)}} \left(\frac{e}{p-1} \cdot \frac{KS}{a}\right)^{p-1} e^{\frac{-KS}{a}}\, d\left(\frac{KS}{a}\right)$$

This expression can be integrated graphically for $p =$ 40, 50, 60 for different values of $\frac{KS}{a}$ (see Fig. 5).

Since $\int_0^{\frac{KS}{a}} \frac{y_p}{y_o}\, d\left(\frac{KS}{a}\right) = \frac{y_{p(\text{average})}}{y_o}\left(\frac{KS}{a}\right)$ and $\frac{KS}{a} = \frac{0.1 \,.\, 4400}{11} = 40$

integration between limits $\frac{KS}{a} = 40$ and 0

for $p = 40$ gives area below the curve = 27 units

where the integration unit per unit area = $0.05 \times 2 = 0.1$,

Hence

$$\int_0^{40} \frac{y_{40}}{y_o}\, d\left(\frac{KS}{a}\right) = 2.7 = \frac{y_{40(\text{average})}}{y_o} \,.\, 40$$

and $\frac{y_{40\ (\text{average})}}{y_o} = \frac{2.7}{40} = 0.0675$

Hence recovery $= (1 - 0.0675)\,100.$

$= 93.25\%$

For $p = 50$ below the curve = 17.2 units

and $\frac{y_{50\ (\text{average})}}{y_o} = \frac{0.172}{40} = 0.0043$

and recovery = 99.57%

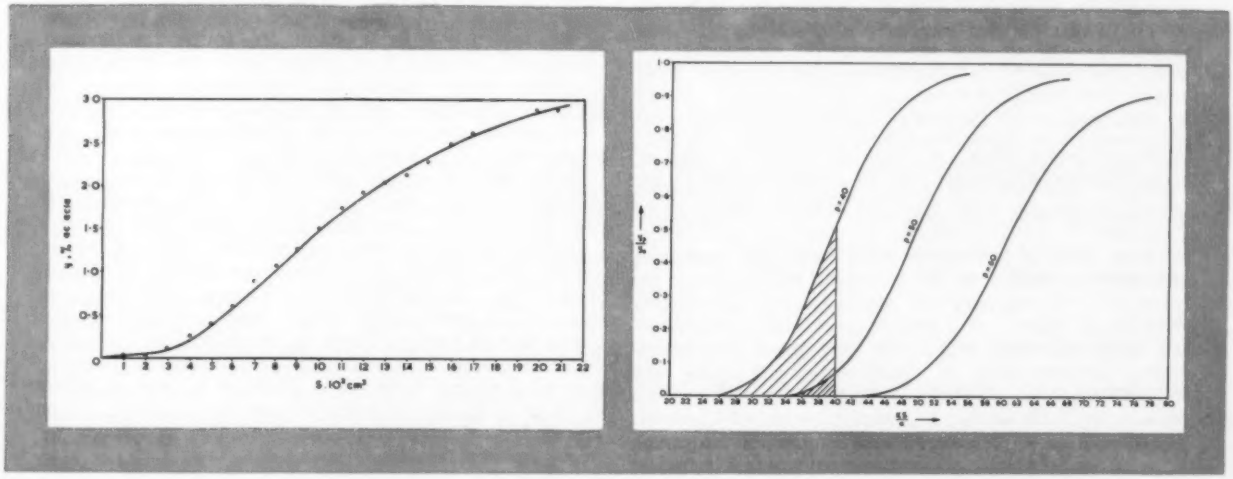
Inspection of Fig. 5 shows recovery in the case of $p = 60$ to be virtually complete.

Example 2

To recover ether vapours from a mixture with nitrogen, the gas is bubbled through a series of absorbers disposed

Fig. 4. Results of dilution experiment to test Equation (15). Predicted results are shown by curve; experimental results by the points.

Fig. 5. Recovery of a solute from a dilute solution by adsorption. Graphical solution for different heights of adsorbent bed.



as in Fig. 1 and filled with m-cresol. Some 1311 cu. m of the gas mixture (substantially at 760 mm Hg and 20°C) containing 2% by volume of vapours are processed per absorption cycle (i.e., up to the moment, the first absorber, enriched in ether, is cut out and a fresh absorber at the end of the series put into use; the gas mixture is then introduced in the second absorber).

Assuming that equilibrium is reached in each absorber, calculate:

(a) Amount of m-cresol in the absorbers if the first absorber is cut out when the exit gas concentration from this absorber is practically identical with that of the inlet gas: i.e. $\frac{y_1}{y_o} = 0.99$.

(b) Number of absorbers if a 90% recovery is desired.

Solution

The partial pressure of ether in 0.15 mol. fraction of ether in m-cresol at 20°C (Perry, *Chemical Engineer's Handbook*, 1950, 678, Fig. 4) = 15.2 mm

$\therefore$ mols ether in mixture $= \frac{15.2}{760} . 100 = 2$

Per 100 mols of mixture weights of each component are 148.2 Kg and 2744 Kg; hence $y = 0.054$ and $x = \frac{15}{85} = 0.1765$

$\therefore K = y/x = 0.306$

and $S = 1500$ Kg, N_2

From Fig. 2 for $p = 1$ and $\frac{y_1}{y_o} = 0.99$

$$\frac{KS}{a} = 4.6$$

hence $a = 99.8$ Kg m-cresol in each absorber.

Alternatively, a may be obtained from $\frac{y_1}{y_o} = 1 - e^{\frac{-KS}{a}}$

Operating Cycle

Each first vessel is put out of circuit when $y_1 \simeq 0.99\ y_o$ i.e., when the absorbent is practically at equilibrium saturation with the inlet gas. This occurs when its ether concentration is -15%.

Now the quantity of ether to be handled, n, is given by $n = (99.8 + n)\ 0.15$; whence $n = 17.65$ Kg.

Since 0.02×1311 m³ of ether, equal to 81 Kg, are fed to the process and since with six vessels in series the recovery is 92.3%, $81 \times 0.923 = 74.5$ Kg of ether are recovered. Hence, the first absorber must be taken out of the circuit after $1311 \times \frac{17.65}{74.5}$ m³ $= 310$ m³ of gas have passed through the system. It also follows from inspection of Fig. 2 that for two successive p values the horizontal line representing $\frac{y_p}{y_o} = 0.99$ intercepts the curves at smaller differences of $\frac{KS}{a}$ for $p = \frac{KS}{a}$ than for $\frac{KS}{a} = (p - 1)$. At large number of p, i.e., when the system is "run in" (equilibrium is established and the system is running like a continuous one), this difference $\frac{KS_p}{a} - \frac{KS_{p-1}}{a}$ has a limiting value of 1.1 which agrees with the previously estimated throughput of 310 m³ of gas mixture.

Number of Stages

Amount of ether lost in the exit gas from the last absorber is $S.y_{p(\text{average})}$ and the recovery is $\left(1 - \frac{y_{p(\text{average})}}{y_o}\right) 100\%$.

The value of $\frac{y_{p(\text{average})}}{y_o}$ can be estimated by graphical integration of $\frac{y_p}{y_o}$ (making use of Fig. 2) between limits $\frac{KS}{a} = 4.6$ and $\frac{KS}{a} = 0$ for different values of p assumed to be necessary for a 90% recovery. For a first trial let $p = 7$, then:

$\int_0^{4.6} \frac{y_7}{y_o}\, d\left(\frac{KS}{a}\right) = \frac{y_{7\ (\text{average})}}{y_o} 4.6$ corresponding to 2.16 units of area (Fig. 2).

Integration unit per unit area $= 0.1 \times 1 = 0.1$ and hence

$$\frac{y_{7\ (\text{average})}}{y_o} = \frac{0.1\ 2.16}{4.6} = 0.047$$

This gives a recovery of 95.3% which is too high. Further trials with $p = 5$ and then 6 gave recoveries of 85.3%, which is too low, and 92.3% which is sufficiently close to the required condition. Hence the number of stages required is 6.

NOTE: It will be noted that at the beginning of the second cycle the absorber which next occupies the first position has already a concentration of ether and it will be cut out of the circuit much sooner than the absorber originally in the first place. The amount of gas which passes through the new No. 1 absorber before it is taken out of circuit can be easily calculated from Fig. 3 by the procedure outlined above. The same considerations apply to the third absorber when it occupies first place in the series.

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Aston's New Laboratory

THE OPENING OF A NEW £15,000 laboratory block at the Erdington (Birmingham) works of the Aston Chain & Hook Co. Ltd., non-ferrous metal engineers, marks an important stage in the development of a policy which gives "the lab" a more than usually prominent role in the activities of the organisation. So far from being a somewhat narrow and specialist department, little concerned with matters outside research and development, the Aston company's new laboratory is now the headquarters of a development department completely integrated with every form of works and staff activity from process control to work study.

Mr. Norman Harvey, who, at 28, is development manager and head of the department, was formerly the company's chief metallurgist and qualified for his M.Sc. degree after being seconded from the factory for a year while he took a full-time course in engineering production at the University of Birmingham. This course was arranged so that Mr. Harvey could get to know something about the wider aspects of industrial management—the human factors in particular. Mr. Bond-Williams, the company's managing director, said at the official opening of the new laboratory: "We hoped that the good technician would develop into an equally good 'management' man, hence this appointment, which gives Mr. Harvey responsibility for all research, development and laboratory services, and such matters as work and method study and labour incentive schemes, in which the human element is of vital importance. This laboratory, even more than my own office, is the nerve centre of the factory, ready to tackle every kind of problem—and, as far as possible, before it becomes a shop floor headache. The old idea of a laboratory as a sort of ivory tower inhabited by men in white coats peering into microscopes and with little practical knowledge of management or shop floor conditions is, in my opinion, hopelessly out of date."

A NEW ITALIAN RUBBER AND FERTILISER PLANT

Production of synthetic rubber and fertilisers is based on methane at Ravenna

THE recently-commissioned plant of the State-controlled company ANIC at Ravenna, Italy, is stated to have an initial capacity of 35,000 tons a year of synthetic rubber and 650,000 tons of fertilisers.

Originally, in 1952, ANIC planned to manufacture rubber only from hydrocarbons containing four carbon atoms, by-products of petroleum refining. It was found, however, that the Italian refineries could not supply sufficient raw material for a plant of 30,000 tons annual capacity, and the company subsequently decided to exploit local natural supplies of methane as the raw material, and to combine rubber production with the manufacture of synthetic fertilisers.

The present establishment covers about 530 acres and lies four kilometres out of Ravenna, along the canal linking the town with the sea. Situating the plant near the sea has solved many problems of materials and product transport and the proximity of consistent deposits of gypsum has permitted the production of ammonium sulphate by a novel double decomposition process. Industrial water, 4-5000 cu. m./h., is pumped along a 16.5-km. canal to serve all the plants. For the chemical works it is treated with zeolite.

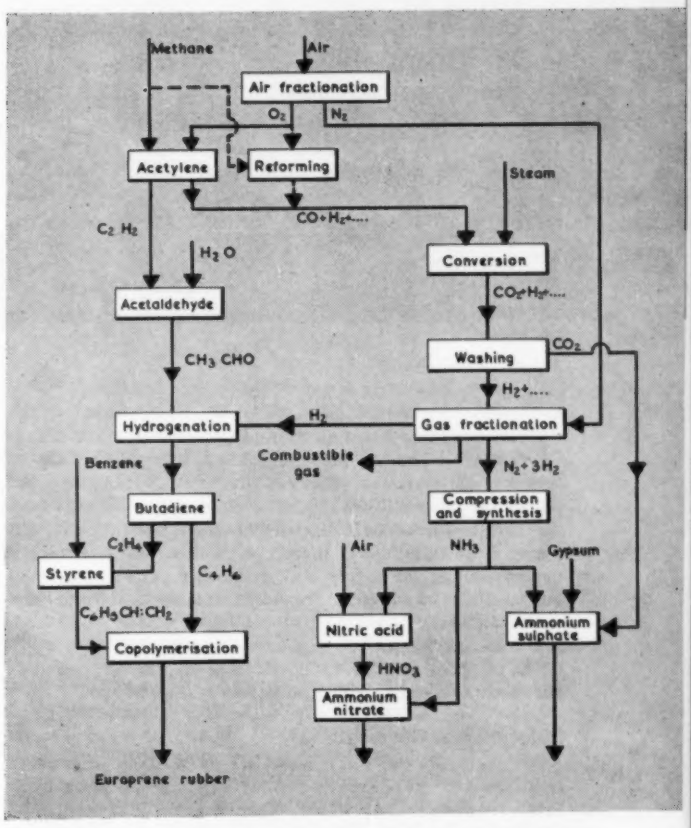
To obtain the skill required in the staff, training courses had to be established and a number of young graduates were sent to America to gain first-hand experience in some of the processes employed.

Integration of Processes

The arrangement of the operations is shown in the accompanying diagram. Oxygen (purity 98%) and nitrogen (purity 99.98%) are supplied by a Linde air separation plant consisting of a compressor house, fractionating unit, air-cooling towers and two 10,000 cu. m. gas-storage units. Before compression, the air is filtered in large centrifugal compressors driven by steam turbines. The oxygen is used for the production of acetylene by the partial oxidation and cracking of methane by the *Badische Anilin und Soda Fabrik* process. After removal of acetylene from the products of the reactions the residual gas is fed into the fertiliser plant. The solvent used for absorption also contains small quantities of gases lighter than acetylene. Those are extracted by degassing, and are either discharged or utilised as combustible gases.

The acetylene is then hydrated to acetaldehyde in two reactors working in parallel. The reactors consist of vertical cylinders containing an aqueous suspension of mercury sulphate together with ferric sulphate and metallic mercury. Small quantities of crotonaldehyde and acetic acid are also formed in the reaction. The vapours of the products are cooled and washed with water to absorb acetaldehyde. The resulting acetaldehyde solution contains small quantities of acetylene and by-products, from which the acetylene is recovered by absorption for recycling.

The next step, the hydrogenation of acetaldehyde and conversion to butadiene, is undertaken by the Union Carbide & Carbon Corporation's process. The conversion reaction is based on the process of Ostromislenksi, who first



Flow diagram showing the arrangement of the process in the production of rubber and fertilisers at the Ravenna plant.

observed formation of butadiene on passing a mixture of alcohol and acetaldehyde over a catalytic mass consisting of kaolin. Both the hydrogenation and dehydration reactors are tubular with the catalytic mass placed inside, and the temperature is controlled by external circulation of Dowtherm. Hydrogenation of acetaldehyde is exothermic and the Dowtherm removes the heat, giving it up later to water in two coolers. The formation of butadiene is endothermic, and the Dowtherm circulating round this reactor is heated in a methane furnace.

Styrene, the other raw material for the copolymerisation, is produced in a plant operating the Koppers process. The starting materials are benzene and ethylene, and these react in the presence of aluminium chloride and ethyl chloride (a source of hydrochloric acid, a promoter). Reaction takes place in a cylindrical reactor, and the temperature must be maintained at 95°C by cooling. The second stage is the catalytic dehydrogenation of the ethyl benzene so produced to styrene.

SBR-type rubber, to which the name Europrene has been given, is obtained finally by copolymerisation using the process of Phillips Petroleum Co., Bartersville. The reaction between butadiene and styrene takes place in an aqueous emulsion, stabilised with soaps, in a double-walled reactor and at low temperature.

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PLANT DESIGN AND OCCUPATIONAL HEALTH

Potential causes of occupational injury and illness of chemical workers are discussed and a provisional specification for safe employment is provided in the form of check lists

by E. F. EDSON, M.B., Ch.B., M.Sc.

THE most important elements in any chemical or manufacturing process are the human beings who are to operate, maintain or supervise the plant. They, like the plant, are susceptible to wear and tear, but, in addition, they are influenced emotionally by their working environment. It is imperative, therefore, that at all stages of a design project the safety and well-being of the plant staff be carefully considered. Successes and failures have provided sufficient knowledge of causes of accidents, poisoning and complaints for a general specification for conditions of employment to be drawn up for the help of chemical engineers. Safety must always be bought.

Safety from the beginning

To build all the safety features in at the design stage may involve more initial capital expenditure than when safety measures are added piecemeal at later stages as "maintenance" items—usually after an accident, illness or complaint by workpeople—but a plant which is virtually safe from the beginning is less likely to be held up later for safety modifications; moreover it can be operated by a wider spectrum of workpeople than a less safe and more demanding installation. When built-in safety reduces the need for operators to wear personal protective devices such as gloves, impervious suits, dust masks or respirators, they will operate the plant more efficiently, because they are less encumbered. A safe plant permits production and supervisory staff to concentrate more on production efficiency, and removes much of the anxiety in operational safety. Every supervisor knows the worrying train of events after a nasty and preventable accident on the plant—investigations, official inquiries, labour replacement, training the new man, reassuring other workers, modifying the plant belatedly, possibly litigation, etc. Accidents and these distracting consequences can usually be prevented by the chemical engineer or designer who knows his job. In general, automatic or involuntary safety measures are much more likely to be successful, human nature being what it is, than those where reliance is continually placed on the individual workman's memory, ability and will to safeguard himself and his workmates.

How can safety be incorporated into design? The three possibilities of injury, illness or indisposition must be kept in mind during all phases of the project. In devising the chemical flowsheet, the injurious or dangerous properties of all process chemicals and materials must be considered. If reliable information or opinion is not immediately available, it should be sought. Some organisations are self-sufficient, and an industrial medical officer, toxicologist or hygienist may be at hand to give expert information and advice. Helpful facts can sometimes be obtained from suppliers of initial process chemicals, solvents, etc. Several useful publications on industrial toxicology and hygiene have come forward in recent years (*vide* Appendix 2). Trade associations and professional societies may be able to fill gaps in the data. The Royal Society for the Prevention of Accidents* provided an excellent advisory service for its members. Even the smallest firm can enlist help from the local District Inspector of Factories, and thus from an organisation which has perhaps a greater fund of practical knowledge of factory hazards than any other. In the complete absence of sound toxicological opinion or data, it is obvious than no negligent risks should be taken, and a cautious approach is to be adopted in handling any unusual chemical until safety is assured. It is in these early stages that chemists should seriously investigate the possibilities of substituting a less dangerous chemical for one which seems likely to be expensively toxic, irritant, explosive, corrosive or inflammable; this is quite often possible with solvents, for example.

The next stage is the *flow diagram*. From knowledge obtained on the properties of the materials featuring in the process, one must now decide what type of vessels, process equipment, plant layout, and handling, control and sampling methods are required for safety. It is at this stage that one decides the broad principles of safety, especially against chemical risks, toxicity, fire, explosion, dust-control, etc.

With the next stage, the *general layout drawings*, comes the need for considering all special arrangements, e.g., the relative positioning and movements of men, machines and materials, the different jobs to be done by operators, safe access for routine or special maintenance and repairs, the siting of all emergency requirements, storage areas, mess

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Fig. 1. Use of a covered washing trough prevents dangerous or unpleasant materials being carried on operatives' boots into change rooms.

Fig. 2. This weed-killer plant building, glass and asbestos clad, æsthetic inside and out, provides controlled ventilation and protects well against weather extremes.

rooms, operating platforms, control points, etc. It is almost essential to call in the help of other advisers, so that nothing important is forgotten or badly devised. Great assistance comes from the availability of a scale or near-scale model of the suggested plant arrangements. Only those who are very experienced can look at a drawing and see tri-dimensionally, and production personnel, work-study officer, medical officer, safety officer, fire officer and any other special advisers called in to comment on the drawings, will be found much more helpful—and quicker to decide and advise—when such a model is available.

A *semi-scale or pilot plant* may be under consideration. Although it is reasonable for some of the finer safety measures intended for the full-scale plant to be omitted or reduced, no liberties should be taken with the health and safety of those who are to operate the plant. Such plants often reveal serious and unforeseen problems in process control, in the flow and handling of materials, the suitability of materials of construction, and the like. They often continue operation for longer than originally intended, and they are housed in structures not lending themselves to safety in the event of an emergency. Furthermore, they are almost certain to be operated in the first place by specially skilled personnel, development chemists, chemical engineers, supervisors or skilled chemical operators. It is sheer folly to omit emergency and other important safety needs, in the expectation that these "experienced personnel" will cope with the problems of the process as well as of their own safety. The medical and toxicological literature contains many interesting articles beginning, "A development chemist was. . . ."

In the final stage of design, that of the *detailed drawings*, the designer's proposals again call for minute examination by those responsible for production, fire-prevention, safety and health. Because modifications during construction are deservedly unpopular, health and safety examiners need to be very thorough at this stage. Adequate time should be allowed, and any tendency to rush through the final checks resisted. Neither designer nor adviser can be expected to have a perfect memory for all conceivable risks and all available safeguards, and the author, and some of his colleagues, have found much value in the use of three-check-lists, as *aides-mémoire* on health and safety matters. Tables 1-3 give the most important causes of industrial injury, illness and indisposition, and for each of these they suggest safeguards from which judicious selection could be made, as best fits the case. Such tables can never be complete, nor a substitute for discernment and intelligent thought. Nevertheless, they do serve to remind those considering safety in design of the large number of possibilities which exist.

Table 1, on physical injuries, and Table 3 on indispositions and inefficiency, need little elaboration. Table 2 deserves special consideration, as chemical risks are much less easy to evaluate and decide upon than mechanical or physical hazards.

Chemical Risks

Risks of occupational illness occur when exposure to chemicals exceeds the capacity of bodily defensive mechanisms to ignore or detoxicate the offensive agent. With local exposures, the effects may be confined to the areas exposed, examples being skin burns, skin ulcers, irritant or sensitisation dermatitis, conjunctivitis, nasal ulceration, bronchitis, gastritis, or even (after prolonged exposure to excessive amounts of carcinogenic materials) malignant growth of skin or bronchial surfaces.

Systemic poisoning may occur when opportunity exists for excessive absorption of chemical into the bloodstream through inhalation of high atmospheric concentrations, or from extensive or persistent skin contamination, or (more rarely) from contamination of food or drink, or (hardly ever) from eye-splashes. Massive absorption during, e.g., emergencies, abnormal plant conditions, or failure of controls, may cause acute poisoning. Toxic effects may then follow within seconds, minutes or hours, depending on the mode of toxic action of the chemicals concerned.

Prolonged exposure to low but unsafe concentrations may eventually lead to toxic effects, often of different type from those seen in acute poisoning by the same material, and taking weeks, months or years to cause illness—chronic poisoning. Whether a material presents risks of acute or chronic industrial poisoning depends mainly on the relationship between the injurious dosage of the chemical, and the concentrations to which the worker's lungs, skin, food and drink are exposed.

The biggest risks of acute or chronic poisoning are from inhalation of dangerous concentrations into the lungs, and from skin contamination. Human lungs offer about 75 sq. m. of sponge-like absorptive surface, and almost all inhaled particles and vapours impact on moist surfaces at which irritation or absorption may occur. Breathing at the rate of about 10 cu. m. of air per shift, with high air-velocities at the nostrils, unprotected man is an effective aspirator of atmospheric contamination. Inhalational risks depend mainly on the order of gas, vapour, fume, mist or

dust concentrations around the worker's face, compared with the concentrations needed to cause local effects or systemic poisoning in man. Neither of these factors can be estimated from theory. It is sometimes possible to guess at the order of magnitude of the eventual vapour or dust concentrations at working zones, but it is usually necessary to confirm these estimates, especially for toxic materials, by air-sampling and sample-analysis during early plant operation. Precautionary measures must then be revised until safety is assured. The only simple and convenient way of telling if an analysed air concentration is "safe" is to compare it with the concentration regarded as safe by toxicologists and industrial hygienists. The term "threshold limit" of a material, as used by industrial hygienists, refers to the highest average concentration which appears most unlikely to cause any adverse effects on workers' health, despite regular daily exposure, eight hours a day, without protection. It is only fair to state here that the "threshold limit" is regarded by many industrial hygienists and medical officers as a somewhat dangerous thing, as it may encourage designers to work in the narrow zone of probable safety, whereas with many toxic substances, the designer's target should be set at zero, to allow for possibilities of failure. A representative selection of threshold values is given in Appendix 1 and, so that designers do not misinterpret, the prefatory note of the Conference of Governmental Industrial Hygienists is included.

The concentration of a vapour or dust actually occurring at a working position will depend on how much of the material is exposed, how much is spilled, agitated or blown about, the temperatures of the liquid and of atmospheric air, ventilation rates in the area, the proximity of worker to source of emission, etc. The complexity of such factors usually defeats design and medical staff. The usual approach is to install the safeguards which seem to be demanded by knowledge of the material's inhalational toxicity compared with estimates on the likely order of atmospheric contamination. Safety provisions are then reviewed after plant and analytical experience, with especial reference to vessel enclosure and ventilation systems.

Absorption through the skin

Systemic poisoning by toxic chemicals absorbed through the skin, especially by organic compounds in liquid form, is probably an even bigger danger than most chemical engineers and industrial hygienists already realise. Human skin should be regarded as a sieve rather than as a barrier. The property of being absorbable through the skin in dangerous amounts depends on factors as yet little understood. Orthodox design features for handling toxic or dangerous liquids are usually thought of by designers, but there is often a tendency to be niggardly with hand-washing facilities actually on the plant, close to the potential sources of hand and skin contamination. Where toxic liquids, or dusts bearing such liquids, contaminate the skin, decontamination often needs to be speedy to ensure non-absorption. Washing facilities sited at inconvenient distances from the working position are of restricted value.

Although experienced designers, especially in large industrial organisations, are well acquainted with the hazards and precautions outlined above, in the author's experience, the design of a major plant is often shared among many chemical engineers and draughtsmen, many of them young, and not yet fully aware of the consequences of inadequate considerations of safety aspects. Perhaps it is fitting to close with the words of Sir Thomas Legge, a pioneer Medical Inspector of Factories: "Unless and until the employer has done everything—and everything means a good deal—the workman can do next to nothing to protect himself, although he is naturally willing enough to do his share." Design in fact for living.

APPENDIX 1
THRESHOLD LIMIT VALUES FOR 1957

(Adopted at the 19th Annual Meeting of the American Conference of Government Industrial Hygienists, St. Louis, April, 1957)

"VALUES are given in the following tabulation for the maximum average atmospheric concentration of contaminants to which workers may be exposed for an eight hour working day without injury to health. These values are based on the best available information from industrial experience, from experimental studies and when possible, a combination of the two. They are not fixed values but are reviewed annually.... Threshold limits should be used as guides in the control of health hazards and should not be regarded as fine lines between safe and dangerous concentrations. They represent only conditions under which it is felt that workers may be repeatedly exposed, day after day, without adverse effect on their health. The figures listed refer to weighted average concentrations of an eight-hour working shift rather than a maximum which is not be exceeded even momentarily. The amount by which these figures may be exceeded for short periods during the workday depends on a number of factors, such as the nature of the contaminant, whether high concentrations even for short periods produce acute poisoning, whether the results are cumulative, the frequency with which high values occur, and for what periods of time. All must be taken into consideration in arriving at a decision as to whether a hazardous situation is deemed to exist. These values are not intended for use or for modification for use, in the evaluation or control of community air pollution or air-pollution nuisances."

The complete list, published in the A.M.A. *Archives of Industrial Health*, 1957, **16**, 261 (American Medical Association) presents threshold limits for nearly three hundred industrial chemicals; those given below are a representative selection.

GASES AND VAPOURS	*p.p.m*	*mg./m.*³
Acetone	1000	2400
Ammonia	100	70
Amyl acetate	200	1050
Aniline	5	19
Arsine	0.05	0.2
Benzene	25	80
Butadiene	1000	2200
Butanone	250	740
Butyl cellosolve	50	240
Carbon disulphide	20	60
Carbon monoxide	100	110
Cellosolve	200	740
Chlorine	1	3
Chlorine trifluoride	0.1	0.4
Chloroform	100	490
Cresol	5	22
Cyclohexane	400	1400
Cyclohexanol	100	410
Decaborane	0.05	0.3
Diacetone alcohol	50	240
Dichlorodifluoro-methane	1000	4950
Diethylamine	25	75
Dioxane	100	360
Ethyl acetate	400	1400
Ethanol	1000	1900
Ethylamine	25	45
Ethyl chloride	1000	2600
Ethyl ether	400	1200
Ethylenediamine	10	30
Ethylene dibromide	25	190
Ethylene oxide	50	90
Fluorine	0.1	0.2
Formaldehyde	5	6
Gasoline (petrol)	500	2000
Hydrazine	1	1.3
Hydrogen chloride	5	7
Hydrogen cyanide	10	11
Hydrogen selenide	0.05	0.2
Isophorone	25	140
Isopropylamine	5	12
Methanol	200	260
Nickel carbonyl	0.001	0.007
Nitric acid	5	25
Nitrobenzene	1	5
Nitrogen dioxide	5	9
Octane	500	2350
Perchloroethylene	200	1350
Phenol	5	19
Phosphorus trichloride	0.5	3
Pyridine	10	30
Stoddard solvent	500	2900
Sulphur dioxide	5	13
Tetranitromethane	1	8
Toluene	200	750
Trichloroethylene	200	1050
Xylene	200	870

DUSTS, FUMES AND MISTS	*mg./m.*³
Antimony	0.5
Arsenic	0.5
Barium (soluble)	0.5
Cadmium oxide fume	0.1
Chromic acid, chromates	0.1
Cyanide (as CN)	5
Dinitro-*o*-cresol	0.2
Fluoride	2.5
Hydroquinone	2
Lead	0.2
Lead arsenate	0.15
Magnesium oxide fume	15
Mercury	0.1
Mercury (organic compounds)	0.01
Sodium fluoracetate	0.1
Sulphuric acid	1
Zinc oxide fumes	15

MINERAL DUSTS	*Millions of particles per cu. ft*
Asbestos	5
Silica (over 50% SiO_2)	5
Silica (5-50% SiO_2)	20
Silica (below 5% SiO_2)	50
Portland cement	50
Talc	20

TENTATIVE VALUES	*p.p.m.*	*mg./m.*³
Beryllium	—	2 γ/m³
Butyl mercaptan	10	35
Ethyl mercaptan	250	640
Methyl styrene	100	480
*PTFE decomposition products	0	0
*Pentaborane	0	0

(*Until more data arise, concentrations should be kept as near to zero as possible.)

APPENDIX 2

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ACKNOWLEDGEMENTS

The author is grateful for the help of the many chemical engineers and designers with whom he has worked, and particularly in the preparation of this paper, to Mr. L. O. Whittaker, Chief Engineer, Fisons Ltd.

Table I. CAUSES AND PREVENTION OF PHYSICAL ACCIDENTS AND INJURIES

Potential Risk	Safeguards to be Considered
Fires and explosions	Replace or isolate inflammable solvents. Segregate hazardous chemicals. "Runaway-reaction" controls. Pressure testing of vessels. Barrier walls. Flameproof or otherwise safe electrical equipment. Bursting discs. Fusible plugs. Relief valves. Non-spark tools. "Pre-explosion" controls. Static discharges. Ventilation for explosible dusts. Fire detectors. Fire alarms. Bins for combustible waste. Water points and hoses. Extinguishers. Emergency exits. Non-spark footwear. Shatter-proof glass at key windows. Control waste vegetation near points of risk, by persistent weedkillers.
Maintenance and repair jobs	Safe access to vessels, pipelines, valves, motors, sumps, roofs, greasing points. Safe lifting facilities for replacements. Safe entry to enclosed vessels, sumps, wells. Purging by water and air for vessels, pipes, sumps. Isolating valves for vessels. Storage and supply of special protective equipment, and clothing. Outline of permit to work procedure.
Moving machinery	Fixed barriers. Guards, fixed or interlocked. Adequate gangway space. Emergency controls, braking systems, runback stops. Warning colours. Warning notices, lights or buzzers. Anti-stroboscopic lighting.
Falls from heights	Handrails: toeboards; catwalks; guards; safe ladders; backguards; handgrips. Even stairway risers. Ground control of routine overhead operations. Lifts and elevators for materials.
Trips and falls on floors	Unobstructed gangways and working positions. Even floors. Non-skid flooring material. Prevention of spread of oils, greases. Chemical or traffic resistant flooring materials.
Unsafe storage of materials	Adequate storage space. Stack size limitation. Stackability of containers. Use of racks, bays, pallets, lifting tackle. Protect stack corners from impact. Facilities for inspection, or removal of defective or leaking container. Weather protection. Keep outdoor storage areas free from excessive vegetation, grass, etc. Storage and supply of protective gloves, footwear, helmets, handling tools.
Burns, thermal	Isolate or insulate hot surfaces of vessels, pipes, equipment. Anti-splutter guards for hot liquids. Warning colour schemes, warning lights. Protective gloves, clothing.
Burns, chemical	Substitution by less aggressive chemical. Segregation, bulk storage and gravity feeding of corrosive materials. Remote controls. Level recorders for vessels. Splash guards, drip trays and shields. Resistant valves, packing, seals, gaskets. Guards for sight glasses. Supports for glass pipelines. Pipeline identification colours. Pressure relief valves. Emergency showers, sinks, hoses; with non-freeze water supply. Siting and supply of protective clothing, gloves, visors. Containers for contaminated tools or implements at use-points.
Electricity	Protected exposed conductors. Earthing. Fuses. Emergency master switches. Low voltage portable handtools and lamps. Avoidance of trailing leads. Avoid wet floors.
Strains from lifting, etc.	Use of hoists, stacks, forklifts, ramps, conveyors, elevators, drum- and carboy tippers, loading platforms. Adequate doorway height. Safe openings of doors.
Deficient lighting	Adequate lighting for maintenance and inspection as well as operations. No black areas. External access lighting. Emergency lighting systems.
Flying particles	Collection or deflection at source. Guards, shields, visors.
Handling materials	Work-study of methods. Specifications for safe containers. Bins for scrap, swarf, waste, junk, sweepings. Correct tools for opening and moving bags, drums, boxes, etc.
Injuries by vehicles	Traffic routing. Level roads, entrances, floors. Barriers. Approach warning lights. Adequate turning space. Warning notices. Safe loading of vehicles.
Analytical controls	Safe access to and safe sampling methods from tankers, vessels, drums, carboys, etc. Transit containers for samples.
Emergency first aid	Telephone. Eyewash bottles, fountain, etc. First aid box for immediate treatment of major or minor injuries. Water point, sink, shower or bath for personal decontamination. Instructions on first aid, electrocution, gassing. Emergency bell.

Table 2. RISKS OF OCCUPATIONAL ILLNESS OR DISORDER

Potential Risk	Safeguards to be Considered
Inhalation of unsafe amounts of dangerous, irritant or unpleasant gas, vapour, fume, mist or dust	Secure reliable information on properties and potential hazards of materials likely to contaminate workplace air. Then keep atmospheric concentrations within safe levels by: e.g. Locating very hazardous processes in specially designed rooms or buildings. Use of totally or mainly enclosed systems of storage, transfer, metering filling, sampling, etc. Use of effective local extraction ventilation at points of vapour or dust emission, using cowl, hood, rim, slot, downdraught, backdraught or updraught methods according to nature of problem. Ensure good natural or forced ventilation of building, avoiding "short-circuiting" from, e.g. window to fan. Check air-extraction effectiveness by use of "cold smoke" (titanium tetrachloride fumes), anemometer, etc. For hazardous dusts, use smooth materials for walls, floors. Avoid ledges, girders, flat surfaces. Supply mobile extraction hoses or equipment for special jobs, e.g. maintenance, routine dust-removal occasional operations. Design against dust-sweeping; supply vacuum lines or cleaner. Avoid unnecessary or excessive heating of toxic volatile materials. Use of drip and spill trays. Check effectiveness of design measures by regular air-sampling and analysis. Where above measures not used, or not adequate despite improvements, provide air-supply hood or face-mask, respirator with approved filter and/or absorbing canister, or other effective breathing device. For plant emergencies, provide number of emergency respirators.
Skin contamination by toxic, irritant, corrosive or sensitising liquid or solid	Secure information on properties of materials of process. Remote handling methods wherever feasible. Prevent skin hazards by contamination control (see Table 1, chemical burns). Facilities for vacuum cleaning of dusty surfaces. Use of gloves or (where specifically advised) barrier creams. Overalls, hoods, footwear. On-plant washing facilities. Off-plant ablutions. Laundering of clothing.
Food and drink contamination	Eating rooms outside plant buildings. Drinking water as jet or fountain. Washing facilities, food storage tins, etc., for near-plant mess rooms.
Special risks **Welding**	Permanent or mobile screens. Special goggles or visors. Effective ventilation against fumes. Protective footwear, aprons, gloves.
X and γ radiations	Shielding of sources to absorb direct and scattered radiation. Remote operation and observation. Area monitoring. Cumulative personal dosage monitoring. Safe custody of mobile sources.
Radioactive materials	Intensive contamination control, with plant area, local and personal monitoring for spread of activity.

Table 3. POTENTIAL CAUSES OF INDISPOSITION, COMPLAINT OR INEFFICIENCY AMONG WORKPEOPLE

Cause	Preventive Measures to be Considered
Excessive noise	Reduction at source. Physical isolation of source. Baffle walls. Sound insulation materials. In last resource. earplugs.
Excessive heat	*Radiant heat*. Complete or partial shielding from heat-emitting surfaces. More remote handling. Provision of shelter areas behind baffle walls. Use of heat reflecting paints. Use of heat-reflecting suits. Avoid impervious clothing unless heat-reflecting. Avoid superimposing excessive humidity. *Humidity*. Remove moisture-laden hot air, steam, etc. direct from sources to exterior. Improve air movement at working positions by natural or forced ventilation, fans. Keep air-temperature low as tolerable. Lightweight porous clothing; as much skin exposure as safely possible. Additionally, extra drinking facilities; and personal hygiene arrangements, e.g. showers, towels, underclothing.
Excessive cold	Conserve warm air by improving balance of ventilation. Warm incoming air, e.g. by process heat. Insulation materials. Duckboards or insulation for cold floors. Alternative door openings downwind. Additional space or radiant heaters. Extra warm clothing; messing facilities.
Unpleasant odours	Control odours at sources, e.g. by enclosure, effective extraction to absorbers, liquid or activated charcoal. For persistent malodours, supply full clothing change. Washing facilities. Plant segregation. Contamination control for spillages; decontamination of absorbent materials.
Draughts	Decrease incoming air velocity by e.g. baffles at entry or giving alternative entries. Warm incoming air.
Dirt	Improve and mechanise handling methods. Enclose methods of handling. Improve dust control in moving materials, especially dry materials. Reduce dust levels, e.g. by wetting. Avoid dust clouding by sweeping, doorway winds, etc. Facilities for washing down plant area and surfaces. Facilities for personal washing; supply and storage of easily-laundered overalls. For special jobs, washable aprons, armlets leggings, etc.
Bad lighting	Investigate quantity and quality of light. Usually, supply more light and more diffuse light. Select correct height, positions, shades, power and intervals for lighting. Reduce glare by using non-glass paints of light or pastel shades. Use of transparent roof or borrowed lighting.
Excessive standing	Seats or stools of correct height, type and stability.
Work in confined spaces	Windows, with a view of at least something. Imitate outdoor lighting intensity. Improve air-movement by e.g. diffuse fans. Use interesting colour schemes.
Pests	Avoid pests by prevention of ingress, breeding or spread. Elimination by use of appropriate non-hazardous pesticides.

AN ECONOMIC STUDY OF HEAT EXCHANGERS

An outline of how petroleum engineers have sought to balance initial cost against future maintenance in evolving optimum heat exchanger designs

HEAT exchangers, both on account of their maintenance and their prime costs, are an important factor in the economy of chemical and other processes. One of the major problems with which designers have to grapple is how to strike the right balance between these two expenses. Some light on the problem was shed in a recent paper* devoted to the experience of some 1500 oil refinery exchangers. The designs included in this two-year study were the products of 25 different manufacturers. Most of them were in the size range 1000-3000 sq. ft, and were of the removable-bundle, floating-head construction. From a statistical survey of the information they collected, the authors found that the average life of a refinery exchanger is about 25 years. They found, when it came to maintaining these exchangers, that in 39 cases bundles had to be replaced in their entirety by new ones, whereas of the remainder, 172 could be retubed using the original tube sheets, support plates and baffles. It was found also that bundles with non-ferrous tube sheets could be retubed about three times (although unskilful rolling can ruin them sooner), while steel-tube sheets can be retubed about four times. Beyond this, distortion of the sheets and general corrosion of the parts make it necessary to replace the entire bundle. In a few instances, redesign, using another tube diameter or layout, is an occasion for getting a new bundle. The life of tubes greatly affects the amount of maintenance and its cost. The average life of exchanger tubes is found to be about seven years, but the life varies considerably according to the type of service. In clean services it may be as high as 20 years, but where the conditions are more corrosive and dirty the average life may be only four years. An example of the latter type of dirty surface might be crude oil.

Cleanings and inspections were other activities which were examined. In the two-year period, 733 tube bundles were removed from their shells for cleaning both inside and outside the tubes; this amounts to a frequency of 0.35 times a year. Of some 2050 exchangers opened for inspection and minor repairs, only some 500 revealed fouled surfaces, and these were cleaned without dismantling the exchangers. The frequency for this type of cleaning was about 0.2 times a year. The total inspections during the period were just over 3000, giving an average inspection frequency of 1.05 per exchanger a year. The authors found that for exchangers whose surfaces remained the cleanest, two- or three-year periods between inspections was ample, but when the duties were very severe it was necessary to space the intervals at four to six months.

The problem of how much excess surface should be installed to reduce the frequency of cleaning was next considered. An excess surface of 20% is likely to give rise to future high maintenance costs, whereas 60% excess usually means too much initial investment; the optimum excess for most cases is about 40%. This means that the fouling factor to be used in evaluating the overall heat-transfer coefficient should be about 40% of the sum of the film resistances calculated for the fluids on the tube side and on the shell side. This margin, however, should not be used willy-nilly, as there are other examples where as little as 15 to 25%, or as much as 60 to 100%, excess surface is the sounder practice. It may be in a particular case that to increase the surface is costly, but chemical cleaning can be used to clean the surfaces and thereby restore performance to the clean surface level. In such a case, the excess surface should be a minimum; but on the other hand there are cases where excess surface will protect a major process unit against enforced shut down for exchanger maintenance. If the excess surface is cheap, it is possible that economy favours something approaching a full 100% of excess surface. If, however, the exchanger tubes corrode and fail, then any excess surface would have been in vain. It is necessary, therefore, that the tubes are of the right material to resist corrosion while, at the same time, the diameter, pitch and layout must allow ready cleaning. Although writing these features into the design means adding to the initial cost, it helps maintenance and thereby reduces future costs.

Of the exchangers examined, the tube materials ranged over (a) carbon steel, (b) ferrous alloys and (c) non-ferrous alloys. There are cases where the use of carbon steel was in doubt, e.g., in coolers and condensers using recirculated cooling tower water, where the problem was to maintain the correct concentration of inhibitors in the water. Where the fouling on the outside of the tubes proceeds at so slow a rate that corrosion will terminate the useful life before fouling does, then a triangular pitch may be used. However, the general tendency at the refinery with which the authors were concerned has been to employ square pitch with cleaning lanes in two directions.

Where ready access to the tube bundle is provided for cleaning, the bundle must be of robust construction. The tube diameter, thickness of support plates and their spacing must all be adequate for the weight of the bundle. Moreover, in assembling the exchanger care must be taken to avoid damaging the baffles or squeezing the tubes together which will reduce access for cleaning.

If the bundles foul badly and need mechanical cleaning then it is necessary to provide a rugged exchanger even for the penalty of higher initial cost. But if cleaning *in situ* with a chemical reagent is effective, then a cheaper design can be used.

* "The Heat Exchanger—an Economic Study", by Atkins, G. T., and Felps, N. O. Contributed to the A.S.M.E.-A.I.Ch.E. Joint Heat Transfer Conference, Chicago, Ill., August 18-21, 1958. A.S.M.E. Paper No. 58-HT-4.

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HYDROGEN FROM PETROLEUM AND ITS USES—PART II*

Outlets for refinery hydrogen and special features of plant construction are reviewed by the authors

by R. P. NORTHCOTT, B.Sc., and H. T. PORTER, B.Sc., A.R.I.C., A.M.I.Chem.E.

Use of Hydrogen Outside Refineries

SO far, hydrogen has only been considered with regard to its use in refineries. At the present time, however, the amount of catalytic reformer hydrogen available to the refiner in many cases exceeds that being used for hydrotreating, but there are a number of other applications which are already finding acceptance, particularly in the U.S.A.

The most important application of hydrogen outside the refinery is for ammonia synthesis, and it has been reported that in the U.S.A. some 10% of the ammonia produced utilises hydrogen from catalytic reforming. For this purpose, of course, it is necessary to purify the hydrogen, and low-temperature separation is probably the most economic way of doing this. A further factor to be taken into account is the quantity of hydrogen required for an economically-sized ammonia unit. An ammonia unit of 100 tons per day capacity is estimated to require the hydrogen from a catalytic reforming unit of at least 15,000 bpd capacity. However, this problem could be overcome if it were feasible to pool the hydrogen from a number of reforming units.

Hydrogen is also being used for the refining of crude benzole. At present nitration-grade benzene is normally refined with sulphuric acid, leading to high losses. With certain types of crude benzoles hydrogen treating at moderate pressure, i.e., up to 1000 psig, is an attractive alternative giving a high yield of nitration-grade benzene, and plants employing this process have been in operation in Germany for some years.[6] Hydrogenation has also been studied for the treatment of crude shale-oil and it has been shown possible by this means to produce a gasolene stock which is of low octane number but is suitable for subsequent reforming.[7] Another application is in the manufacture of town gas, and interest is being shown in the hydrogasification of reduced crudes and bituminous coal to produce gas containing a high proportion of methane with a heating value of 900 to 1000 Btu/scf.[8]

The metallurgical industry has also become very interested in hydrogen recently. In several locations manufactured hydrogen is being used to reduce iron ores and in the production of metallic nickel. Although hydrogen would appear to be competing, in this case as a reducing agent with low-price coke, lower capital costs are claimed than for blast furnaces or similar smelting plant and the process can be completely continuous. This application appears particularly promising for countries with a petroleum industry and access to metal ores but with little solid fuel.

Practical Aspects in Petroleum Refineries

While the techniques of handling hydrogen in the chemical and other industries have been developed over many years, they are not necessarily suitable for employment in the petroleum refineries. Further, hydrogen possesses properties which differ markedly from those of the hydrocarbons to which refineries are accustomed. The most important physical differences are shown in Table 1 and the much greater thermal conductivity, specific heat and, particularly significant from the safety aspect, the very wide limits of inflammability are immediately apparent. The petroleum refining industry has therefore had to adapt its own and also other industrial techniques to deal with the presence of these vast quantities of hydrogen and the associated processes.

Principles of Process Design

In a catalytic reforming process, the conditions required to effect the feedstock conversion while preserving the catalyst life will have been determined by pilot-plant experiments. In general, therefore, the designer's problem is one of scaling up and this particular type of process, where the reactants are wholly in the vapour phase, presents little difficulty. Of the several reactions taking place, that of dehydrogenation is highly endothermic and is also the fastest. To obtain the optimum conversion from a catalyst charge, the closest practicable approach to isothermal operation is required. With platinum catalysts this is achieved by using several reactors with intermediate heaters and with the leading reactors smaller than the following ones where the slower reactions predominate. An alternative approach with less expensive catalysts, such as molybdenum oxide on alumina, has been to use a fluid bed which gives completely isothermal operation.

Maintenance of catalyst activity, particularly with expensive platinum catalysts, is of prime importance. Deactivation can occur through coke lay-down from side reactions and this can be minimised by the use of a high hydrogen partial-pressure and a large recycle of hydrogen to the reactors with the feed. It is possible with some catalysts to remove the coke by carefully controlled combustion. Removal of catalyst poisons by hydrotreating the feed has been touched on earlier in this article, but the designer may

* Part I was published in the October issue, pp. 542-5.

TABLE 1—PHYSICAL PROPERTIES OF HYDROGEN AND SATURATED HYDROCARBONS FROM PETROLEUM

Property	H_2	C_1	C_2	C_3	nC_4
Boiling point (760 mm.), °C	−253	−161	−89	−42	0
Critical temperature, °F	−240	−116	90	206	306
Critical pressure, psig	188	673	708	617	551
Viscosity, micro-poises at 25°C	90	125	115	92	85
Thermal conductivity, Btu/hr ft² °F/ft ...	0.100	0.017	0.0100	0.009	0.008
Specific heat (*Cp*), Btu/lb °F at 25°C and 1 atm	3.50	0.55	0.46	0.44	0.42
Inflammability limits in air, % vol.:					
Upper	74.0	14.0	12.5	9.5	8.5
Lower	4.1	5.3	3.2	2.4	1.6
Solubility in hydrocarbon oil (kerosene), vols. at ntp/vol. oil at 760 mm. and 25°C	0.06	0.44	4.5	12.7	79.8
Effect of temperature on oil solubility ...	Increases	Decreases			
Calorific value (gross):					
Btu/scf	325	1013	1792	2590	3370
Btu/lb	61,100	23,829	22,320	21,661	21,308

in some circumstances find it more economical merely to prevent these impurities from building up in the recycle gas by the use of some appropriate treatment.

The major difficulty encountered in the design of hydrotreating units is that the catalytic reformer hydrogen that they use contains a considerable quantity of hydrocarbons, in particular methane. It is therefore necessary to ensure that these hydrocarbons do not build up in a reaction system to the detriment of the required hydrogen partial-pressure. In general, two distinct types of processes are employed. When there is a large excess of hydrogen available, the gas is mixed with the feedstock, heated to the appropriate temperature, passed over the catalyst and cooled to a convenient temperature for separation of product and gas. The residual hydrogen is then available for further use and in this type of process the hydrogen concentration in the reaction zone is dependent almost entirely on the concentration of hydrogen in the catalytic reformer gas. To obtain the required hydrogen partial-pressure the operating pressure must therefore be raised in inverse proportion to the concentration of hydrogen in the original gas. In processes where the feed is vaporised, it is usually necessary to use sufficient excess hydrogen gas to overcome the dilution effect of the hydrocarbon vapours; this excess hydrogen may vary from several to many times the quantity actually consumed in the reaction.

More generally, however, the quantity of hydrogen available, although adequate for the reactions, is insufficient to provide the required excess and recycle of the residual hydrogen in the reactor effluent is then adopted. It is then necessary to remove the methane and other light hydrocarbons brought into the reaction system with the hydrogen and also those produced by the reaction itself. This removal is usually accomplished by solution in the liquid product and also by purging off a part of the recycle gas. An additional hydrogen enrichment step may be necessary, such as oil washing of the recycle gas. The conditions of separation between the recycle gas and the liquid product have, under these conditions, a considerable effect on the hydrogen concentration in the recycle gas, and hence on the hydrogen partial pressure in the reactor. The process employed in the Kwinana hydrofiner, described in Part 1, is typical of the recycle process.

Operating pressures for hydrotreating units are therefore appreciably higher when catalytic reformer hydrogen is used instead of manufactured hydrogen, approaching 100% purity. As an alternative, enrichment of the catalytic reformer-hydrogen could be undertaken, but the separation between hydrogen and methane is not easy to accomplish. Enrichment by oil absorption is possible, but recovery of hydrogen is low and absorbent circulation rates high, as indicated in Table 1 by the low solubility of these gases; their relative volatility is also low. Other possible processes are active carbon adsorption, low-temperature liquefication, and selective absorption such as the Rectisol process of Lurgi. Such separation processes are costly, but despite this their use might be justified to enable considerable reductions in hydro-treating plant costs to be made.

Once the main features of the process have been established, i.e., once-through, recycle or enriched hydrogen and the appropriate process conditions chosen, detailed design of the equipment proceeds. A knowledge of the vaporisation of the feedstocks under the various conditions encountered in the process is then required. While vaporisation calculations for predominantly hydrocarbon mixtures encountered in the petroleum industry are very reliable, it has been found that misleading results may be obtained for systems where there is a large molar excess of hydrogen. In general, there is considerably less vaporisation than would be expected from such calculations. However, by the use of empirical corrections based on experimental determinations, the accuracy of the calculation method can be substantially improved.

When the phase conditions within the reaction system have been established, the remainder of a process design for a hydrotreating unit follows conventional procedures. It may be noted that much higher heat-transfer rates can be achieved in tubulars between fluids containing hydrogen than would be expected from systems containing so much fixed gas. These high rates appear to be related to the high thermal conductivity of hydrogen and, in the case of mixed-phase streams, the very high turbulence between gas and liquid.

Materials of Construction

Hydrogen attack of carbon steel may occur above 200 psig and 400°F, whereas the refinery processes employing hydrogen operate mostly at much higher pressures and temperatures. Alloys containing quite small concentrations of chromium or molybdenum, or both, will withstand much more severe conditions: for instance, steel containing 0.5% molybdenum will successfully resist hydrogen attack at 800°F and 500 psig. The paper by G. A. Nelson[9] is regarded as the standard reference on this subject, while an interesting account of practical experience with refinery hydrogen processes has been given by Ciuffreda and Rowland.[10]

Usually, however, the presence of hydrogen sulphide necessitates the use of much higher alloys than those required to resist hydrogen attack alone. Above 500°F it is the usual practice to use austenitic 18/8 stainless steels, although with low hydrogen-sulphide concentrations it is sometimes possible to use intermediate alloys such as 12/13% chrome steels. Where welding is employed, correct stabilisation of the stainless steel by additions of titanium or columbium (types 321 or 347) is extremely important. The resistance to corrosion required is often greater than that necessary for mechanical strength alone, as the corrosion products from the steel can be carried forward on to a catalyst bed, causing a blockage and bringing the process to a standstill. An excellent survey of hydrogen sulphide corrosion in refinery processes has been made by Sorrell and Hoyte.[11]

Special Constructional Features

The simplest, and safest, construction for a hydrogen process plant reactor is clearly stainless steel. The reactor for the Kwinana hydrofiner was in fact made of this material. For such a vessel, which is fairly small (3 ft 11 in. i.d. × 17 ft 0 in.), solid stainless steel is not too expensive, but for larger vessels the cost becomes prohibitive and alternatives have been sought. Carbon steel or low alloys, such as ½% molybdenum steel, may be lined with refractory to keep the metal temperature low enough to avoid corrosion, or alloy steel liners may be used. Most lined vessels, although cheaper than solid stainless steel, have their drawbacks, which nevertheless are often acceptable under suitable conditions. Some typical reactor designs are shown in Fig. 4.

Another property of hydrogen that requires special design treatment is its power to leak or diffuse through materials quite impervious to hydrocarbons. Welded joints for pipework, especially at high temperatures, are preferred with the minimum number of valves. Where furnace tubes of alloy steel are used, headers can be replaced by welded bends, as the resistance to oxidation permits removal of coke deposits by burning out instead of mechanical cleaning; the measurements of the tube wall-thickness are then not so satisfactory as it can only be done indirectly. The welding of alloy steels, particularly the 18/8 stainless steels, requires very strict conformity to well-tested procedures, if porosity and cracking are to be avoided. Where strip lined vessels are used, vent holes behind each strip in the backing plate are necessary to release hydrogen that diffuses through the alloy steel liner. This hydrogen would otherwise accumulate behind the liner and eventually rupture it.

The special designs of flanged joints used in high-pressure hydrogenation plants are not necessary for refinery hydrogen process units, as the pressures employed are quite moderate. Ordinary ring-type joints are quite satisfactory and the rings may be soft iron or, where corrosion or hydrogen attack requires it, steel alloy of suitable ductility. Small fittings are usually of the socket welded type rather than screwed. For heat exchangers, U-tube or hairpin types are preferred to floating heads to minimise leakage, and the tubes are usually seal welded into the tube plates.

Gas compressors of normal design may be used in hydrogen processes, although somewhat more elaborate piston-rod glands are often used to reduce leakage. These glands are usually labyrinth ring packings suitably vented to conduct any leakage away from the locality of the machinery. Catalytic reformers may require compressors with non-lubricated cylinders to avoid contamination of the catalyst with lubricating oil. The pistons of these machines consist of a number of carbon discs between steel end plates and they are fitted with segmented carbon piston rings. These machines run well, provided no liquid or solid enters the cylinders.

Safety Considerations

While petroleum refineries are well organised and equipped to deal with inflammable hydrocarbon liquids and gases, the fire and explosive hazards are greatly increased with hydrogen because of its much wider limits of inflammability. A frequent additional hazard is the presence in the hydrogen gas-stream of hydrogen sulphide, which is extremely toxic.

Ignition of escaping gas can, of course, occur by means of naked lights, such as furnaces or by sparks from elec-

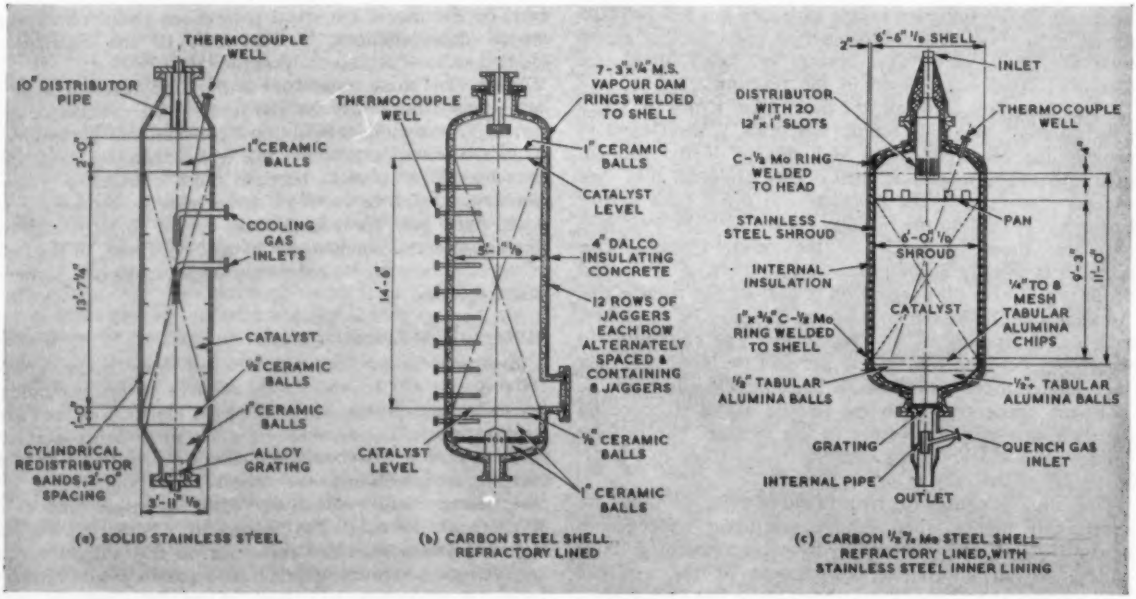

Fig. 4. Typical reactor vessels for petroleum hydro-treating processes.

trical equipment, but it can also occur spontaneously when the escaping gas stream is at a high temperature. Pyrophoric iron sulphide is always a potential source of ignition; some catalysts are also pyrophoric when in the reduced state. The essential safeguards are sound engineering design and strict adherence to correct operating procedure. The engineering design must be adequate to avoid leakage, as discussed above, but it must also ensure that if an escape does occur it is readily dispersed and not ignited. Open-air plant construction is used, and where shelter has to be provided (for example, over compressors to permit maintenance in all weathers) the building sides are left open as far as possible. Oil- or gas-fired furnaces for feed heating are usually a necessary part of the installation and these must be sited as far away from other equipment as layout considerations permit.

The electrical equipment for hydrotreating processes has presented a problem, because none is available that is Buxton certified as flameproof with hydrogen. The difficulty is that, for hydrogen, the width of gap required to prevent the emergence of flames is too small for the commercial manufacture of motors, switchgear, etc. For motors, the solution is to enclose them and keep them under a slight positive pressure with air. Lighting fittings of standard flameproof pattern are accepted, but they are installed outside the windows of buildings. Intrinsically safe control circuits can be designed where the intensity of any possible spark would be insufficient to ignite hydrogen. Flameproofing of the high-tension ignition systems of gas engine drivers for compressors is considered impracticable, but the leads are kept very short by installing a spark coil adjacent to each sparking plug.

Safe operating procedure consists of avoiding the presence of hydrogen and air together inside the plant at all times. If sufficient inert gas or nitrogen is available, air at start or hydrogen at shut-down can be displaced by purging. Alternatively, the unit may be evacuated, usually by a steam ejector, and then filled with nitrogen or inert gas and again evacuated; this operation is repeated several times.

To sum up, it may be said that the quantity of hydrogen available from petroleum is large, is increasing and it is being put to many different uses, both inside and outside the petroleum refineries. As has happened before, the petroleum industry has rapidly and successfully adapted its refining techniques to meet changing circumstances.

The authors thank the chairman and directors of the British Petroleum Co. for permission to publish this paper.

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Institute of Seaweed Research

The Third International Seaweed Symposium recently took place at Galway, Ireland. British work on seaweed is leading to production of chemicals on a semi-commercial scale

THE Scottish Seaweed Research Association was formed in 1944 to examine the seaweeds of Scotland and to determine the possibility of creating a Scottish seaweed industry. At this date the alginate industry had been established and, after it had been shown that not less than a million tons of seaweed was available, work was directed towards chemical investigation of the composition of seaweeds and the development of methods for the extraction of these chemicals.

The Association moved to its present premises at Inveresk in 1947. From that date the laboratories have been known as the Institute of Seaweed Research. In 1951 the Association was dissolved, and its place taken by the Treasury-financed Institute of Seaweed Research so that the latter name then referred to both the organisation and the building. The Institute was fully equipped for botanical, chemical work and also for pilot scale manufacture. Seaweed surveys indicated that about 10 m. tons of seaweed were available and that the annual harvest of 1 m. tons could be taken without depletion of the crop. Chemical work established the constitution of the various species of seaweed and part of the work was then directed to supporting the new use of seaweed meal in animal feedingstuffs and fertilisers. This was followed by the development of methods for the extraction of chemicals, notably mannitol, laminaria and fucoidin, from the algae and the synthesis of potentially more valuable chemicals from the algal carbohydrate laminarin. By following through on a pilot scale, sound methods were developed for the manufacture of these chemicals and their derivatives.

A method for the production of mannitol was completed at the same time as a successful reduction of sucrose to mannitol had been achieved and commercial interest in the project waned. However, a French firm recently announced that they had a unit making 1 cwt. per day and are to erect a unit producing several tons per month. The production of laminarin and fucoidin was also achieved on a pilot plant scale and a market evaluation of the products suggested that soluble derivatives of laminarin might be useful blood plasma substitutes or the sulphate might have anti-clotting properties.

This work completed the Institute's remit and H.M. Government, on the advice of the Advisory Council on Scientific Policy, decided that technological studies should be discontinued. The Institute's laboratories were then sold to the Arthur D. Little Research Institute. The two organisations are separate entities and since 1956 the Institute of Seaweed Research has been mainly concerned with the support of fundamental algal studies at the Universities, the provision of information, advice and technical assistance to interested parties and to stimulate interest in the chemicals obtainable from seaweed. The main industrial interest is now centred on fucoidin, a sulphated polyfucose sulphate which occurs in those seaweeds which grow in the intertidal zone and in the sulphates of laminarin, a carbohydrate which is extracted from sublittoral seaweeds. These products were first developed at the Institute several years ago and showed promise as anticoagulants. More recent work has shown that both these compounds have antilipaemic activity. Considerable interest in these compounds has been evident for the past year and the published results indicate that their activity is caused *in vivo* by the liberation of a "clearing factor". Laminarin and fucoidin are being produced on a semi-commercial scale by Liverpool Borax Co. Ltd.

The Institute's grant for the past year was £7,709. Its research programme is largely academic and is essentially a continuation of earlier studies. Information on all aspects of seaweed and its utilisation is freely given by the Institute's staff and technical assistance is available for the producers and consumers of seaweed and its products.

669-162-2 : 66-074-5

Fig. 1. One of the largest blast furnaces to be erected in Spain, measuring almost 200 ft from ground level to highest point with a hearth diameter of 27 ft. Photo: Head, Wrightson & Co. Ltd.

COMPOSITION AND VARIABILITY OF BLAST FURNACE GAS WASH WATERS

Preliminary studies of a particular blast furnace gas-cleaning circuit led to this report outlining the problem and suggesting a possible and inexpensive solution

by F. EDELINE, Ingénieur A.I.Gx.

THE washing circuit studied treats the gas from four blast furnaces by four different types of equipment. The total consumption in wash water is 1400 cu. m. per hour distributed as follows:

Zschockes:	600 cu. m. per hour.	(Z)
6-washers:	400 cu. m. per hour.	(6-W)
Electrical purifiers:	350 cu. m. per hour.	(EE)
Disintegrators:	60 cu. m. per hour.	(D)

This consumption of water is continuous for all the units of equipment but the electrical purifier demands, in addition, a wash by 30 cu. m. of water every four hours. Fig. 2 shows how the equipment is situated in the gas circuit.

Nature of Material in Suspension

The used waters leaving each unit of equipment have a characteristic composition. Table 1 presents the mean of determinations carried out three times a day for one week.

The composition of the deposit remained practically invariable during the course of the week, which gives a real significance to the differences which can be observed between the columns of Table 1. These differences have two causes—the principle of the washing apparatus and its place in the gas-washing circuit. Thus the Zschockes and the 6-washers, which are both based on entrainment of dust by a shower of water, retain very similar proportions of all the elements, principally the most dense. The disintegrator placed in series after them scarcely gathers more than the minerals of the gangue. As for the electrostatic precipitator, it shows a much less selective action.

Francis Edeline, *chemical engineer and agricultural industries engineer at Institut Agronomique de l'Etat at Gembloux, 1953. Since 1955 attached to Centre Belge d'Etude et de Documentation des Eaux in the residuary water section.*

TABLE 1. Characteristic Composition of Gas Wash Waters

Equipment	*Units*	*Z*	*6-W*	*EE*	*D*
Material in suspension	mg/l	770	450	1415	660
Material capable of sedimentation	ml/l	3.12	3.28	12.9	8.5
Analysis of Deposit:					
Carbon	%	9.6	7.5	5.2	2.9
Siliceous residue	%	13.2	13.8	19.8	31.4
Fe_2O_3	%	29.1	24.1	18.6	6.8
FeO	%	13.1	14.8	8.8	3.3
CaO + MgO	%	11.7	10.3	15.6	20.3
Al_2O_3	%	6.4	9.6	11.6	16.5
Analysis of Water:					
*p*H	—	7.7	8.2	7.9	8.4
Total hardness	°F	38	54	50	74
Chlorides	mg/l Cl^-	324	315	311	368
Dissolved iron	mg/l Fe	0.03	0.03	0.03	0.03

Variability of the Concentration

The concentration of the used water shows profound variation with time, as clearly shown in Table 2.

The main cause of these variations is, of course, the periodicity of the washing. In principle, each of the units of equipment operates with a continuous flow of water, but, as previously mentioned, the electrical purifier is

TABLE 2. Variation of Concentration of Used Water

Equipment		*Units*	*M*	*6-W*	*EE*	*D*
Material in suspension	min.	mg/l	1350	859	5900	1915
	max.	mg/l	328	134	332	26
Material which can be sedimented	min.	ml/l	7.5	6.25	50	32
	max.	ml/l	1.2	0.75	2.7	0.1

washed every four hours by 30 cu. m. of water. It is noteworthy that this plant shows the widest variation of concentration. The Zschockes are similarly washed from time to time, yielding a used water containing 210 g/l of matter in suspension.

Possibility of Simple Decanting

If these used waters are treated by static decantation for two hours, for example, it is found that whatever is the composition of the crude water there remains about 60 mg/l of solids in suspension in the decanted water. This is evidently a residual concentration composed of extremely fine solids which it is not reasonable to hope to dispose of by a simple treatment. On the other hand, if the speed of fall of different particles is calculated under the conditions in which the static decantations trials were carried out, it is found that they correspond to the elimination of all the particles of diameter approximately $\geqslant 10\mu$. However, the calculation of a decantation tank necessary to obtain an equivalent result gives, for a typical factory, 30 m. × 30 m. × 3 m., assuming a current velocity of 15 m./hr. It is not always possible to have available such a considerable space and, in addition, the problem of clearing out the deposited slime makes it necessary to have available two such tanks. The daily volume of moist slime in such a case would be 200 cu. m.

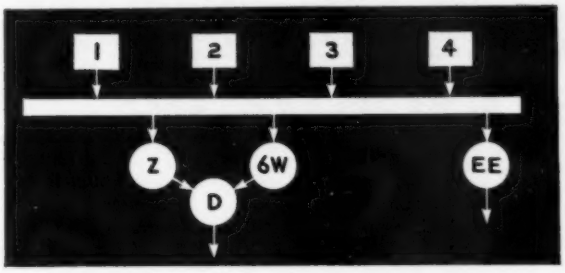


Fig. 2. Schematic diagram showing the arrangement of washers for blast furnace gases.

Counter-current Washing

Before considering more expensive solutions, it is advisable to examine if it is not possible to remedy the two most troublesome characteristics of the used waters, namely the large quantity and the low concentration. To do this an attempt should be made to run the gas and water in counter-current in the washing units. In the case considered, it would be possible to employ the used water from the disintegrators (200 m.³/hr of water lightly loaded with ferrous particles) to feed the Zschockes or the 6-washers. Well-defined standards do not seem to exist for the composition of water intended for washing and this trial is worth carrying out. This counter-current operation would lead to an economy of 15% of volume in the water used with a corresponding gain in the concentration. The only factor which could eventually cause difficulties in using this system is the temperature of the waters for re-utilisation. In fact, one of the roles of gas washing consists equally in cooling the gases and it is evident that this function would be less well assured by a counter-current arrangement.

Flexible Barge for Bulk Transport

A SNAKE-LIKE "barge"—called a Dracone—was recently demonstrated at Southampton Water as a device for the bulk transport of fluids. The vessel, weighing 1 ton, and towed by an 8-ton launch, carried a 37-ton load of kerosene for the demonstration but was stated to have been successfully used at other times to transport 45 tons of fresh water. A conventional tanker of equal capacity has an unladen weight of 90 tons. There is no air space in the Dracone, which is entirely filled with cargo, so that no explosive air-gas mixtures are formed at any stage.

A "stressed skin" construction has been used. The skin, which is $\frac{5}{32}$ in. thick, consists of a woven nylon fabric, with synthetic rubber coatings inside and out. Eyes are fitted at nose and stern for attaching ropes for towing and mooring, for buoys and floats with flags and navigation lights. At the stern there is an Avery Hardoll self-sealing, quick-acting hose connection for emptying and filling through a 4-in. hose. Connections for measuring internal pressure are also provided. A special stabilising device has been attached to the stern. Without this device the barge would snake and yaw from side to side.

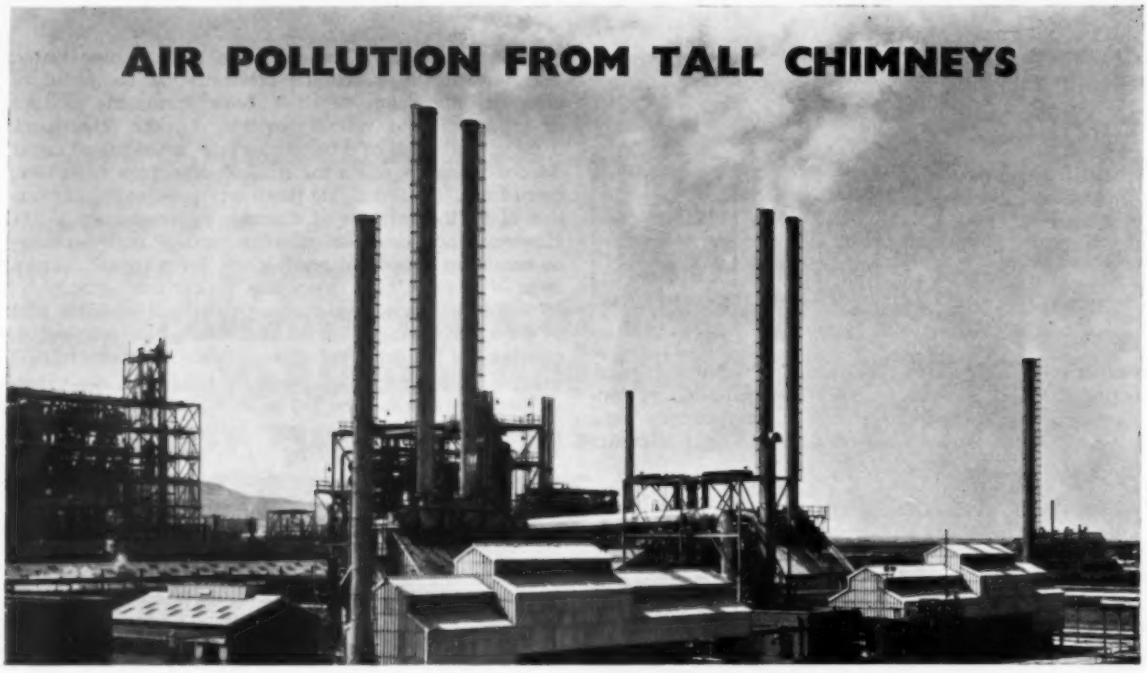
When it is empty the barge can be wound on to a large floating reel which can be lifted on to a quay or pulled up a beach or slipway. The reel used for carrying the wrapped-up barge is a squirrel cage 9 ft long and 5 ft in diameter with internal buoyancy tanks at each end of the squirrel cage of aluminium tubes. The nose of the barge is drawn through the bars of the squirrel cage just as the end of a film is inserted through a slit in the drum of its reel. Reels carrying wrapped-up Dracones can be transported in boats, trains or by lorries.

The model shown was considered to be of operational size particularly suited for inland waterways. Some sea trials have been carried out and more have been planned—the barge being fully instrumented for the tests. This size is regarded as a preliminary step to barges of much higher capacities.

The present Dracone will carry any liquid lighter than water. With petroleum oil, 15 to 20% of its volume shows above water; with fresh water the barge is almost fully immersed. However, the system can be used for the transport of many types of liquids and certain powdered solids in flexible containers of various sizes. With denser liquids, buoyancy tanks might be necessary. Apart from transport uses, the system is also suitable for liquid storage.

The whole project stems from ideas for flexible barges conceived by PROF. W. R. HAWTHORNE, F.R.S., SIR GEOFFREY TAYLOR, F.R.S., and MR. J. C. S. SHAW, M.A., of Cambridge University. An early study of theoretical problems of containing oil in a flexible skin and floating it in water led to experimental work which proved successful. A company, Dracone Development Ltd., was then formed with the support and financial backing of the National Research Development Corporation. Further developments have been sponsored by these two bodies.

AIR POLLUTION FROM TALL CHIMNEYS



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by W. STRAUSS, M.Sc., M.E., and G. WOODHOUSE, B.Sc.*

A nomographic method of calculating ground-level pollution from an elevated point source

THE new emphasis on clean air stresses the importance of designing chimneys to give adequate dispersal to waste gases, particularly if they contain appreciable quantities of sulphur dioxide or other noxious materials, as well as for draught. From these nomograms, which have been based on the equations by BOSANQUET *et al.*,[1, 2] it is possible to estimate the maximum ground-level concentrations of gases or airborne particulate matter under varying stack and wind conditions and, assuming inversion conditions in the atmosphere, which cause the plume to descend.

The "effective height", H, of a stack is the sum of the actual stack height, H_s, and two additional factors: the rise of the gases due to their velocity on leaving the stack (H_v) and the buoyancy rise (H_T), which is a function of the temperature of the issuing gases and the atmospheric temperature conditions. Both H_v and H_T depend also on the wind velocity.

$$\text{i.e., } H = H_s + H_v + H_T \qquad \ldots.(1)$$

Formulæ by BOSANQUET *et. al.* give reasonable estimates of the velocity and buoyancy factors. These are:

$$H_v = \frac{4.77}{1 + 0.43v/u} \cdot \sqrt{\frac{Qu}{v}} \qquad \ldots.(2)$$

$$\text{and } H_T = 6.37\, g \cdot \frac{Q\triangle}{v^3 T_1} \cdot Z \qquad \ldots.(3)$$

$$\text{where } Z = 1n\, J^2 + 2/J - 2 \qquad \ldots.(4)$$

$$\text{and } J = \frac{v^2}{\sqrt{Qu}}\left(0.43\sqrt{\frac{T_1}{gG}} - 0.28\,\frac{u}{g}\,\frac{T_1}{\triangle}\right) + 1 \qquad \ldots.(5)$$

When the effective stack height has been determined, the maximum ground-level concentration, which occurs about 10 to 15 equivalent stack heights (10 to 15 × H) away from the base of the stack in the downwind direction, may be found from:

$$C_{max.} = 2.15 \,.\, 10^5 \cdot \frac{Q'}{v\,H^2} \cdot \frac{p}{q} \qquad \ldots.(6)$$

In the calculations several assumptions have been made:

(i) the ratio of the BOSANQUET and PEARSON turbulence parameters, p/q, is a constant (0.63), which is reasonable for average or moderate turbulence;

Symbols Used

C_{max} = ground-level concentration maximum—units in text;
G = gradient of atmospheric temperature taken as 6°C rise per 1000 ft height = 0.006°C/ft;
g = acceleration due to gravity, 32.2 ft sec.$^{-2}$;
H = effective stack height, ft;
H_s = actual stack height, ft;
H_T = plume height due to buoyancy factors, ft;
H_v = plume height due to velocity of issuing gases ft;
p, q = BOSANQUET and PEARSON turbulence parameters, dimensionless;
Q = total gas rate, measured at the temperature T_1, cu. ft sec.$^{-1}$;
Q' = rate of emission of pollutant gas (at T_1), cu. ft sec.$^{-1}$;
T_1 = temperature at which density of stack gases equals that of the atmosphere. This is usually not much different from atmospheric. and is here taken to be 15°C (59°F), i.e., 288°K;
u = actual gas velocity in stack exit, ft sec.$^{-1}$;
v = wind velocity, ft sec.$^{-1}$;
J *and* Z = parameters; and
$\triangle$ = temperature difference between actual flue gas temperature and T_1, °C.

In the present system, Q, Q', u, v and $\triangle$ are taken as variables, on which C depends, and all other factors are assumed constant.

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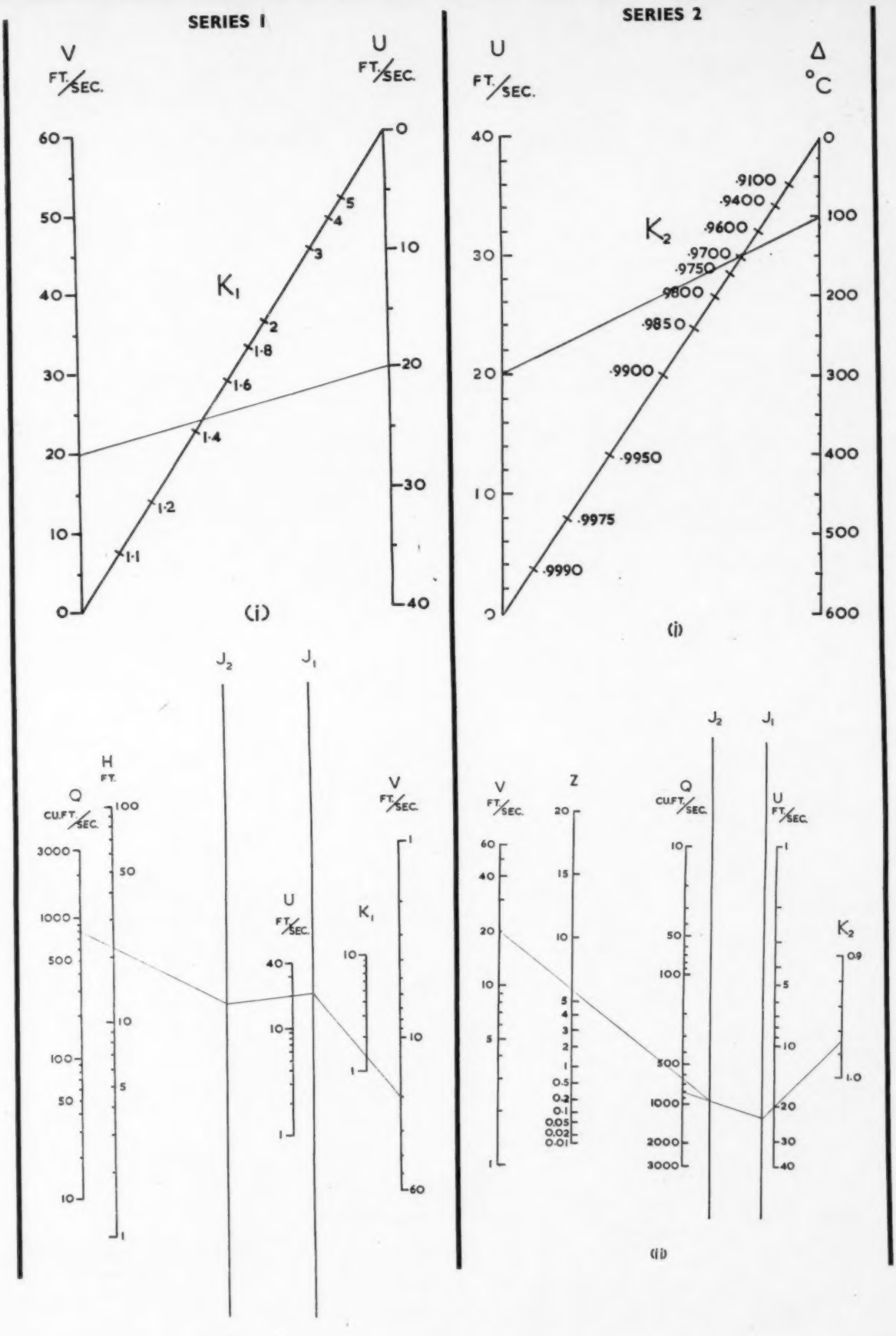
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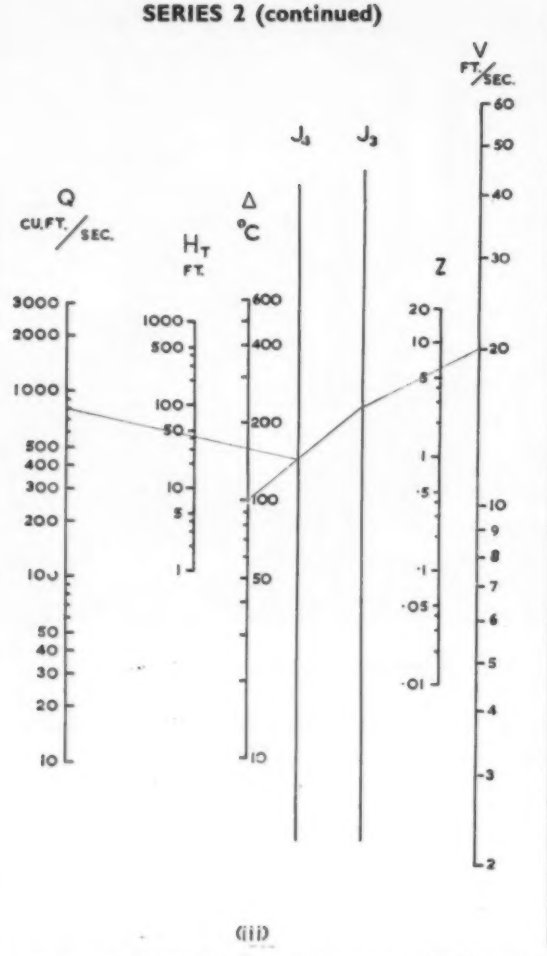

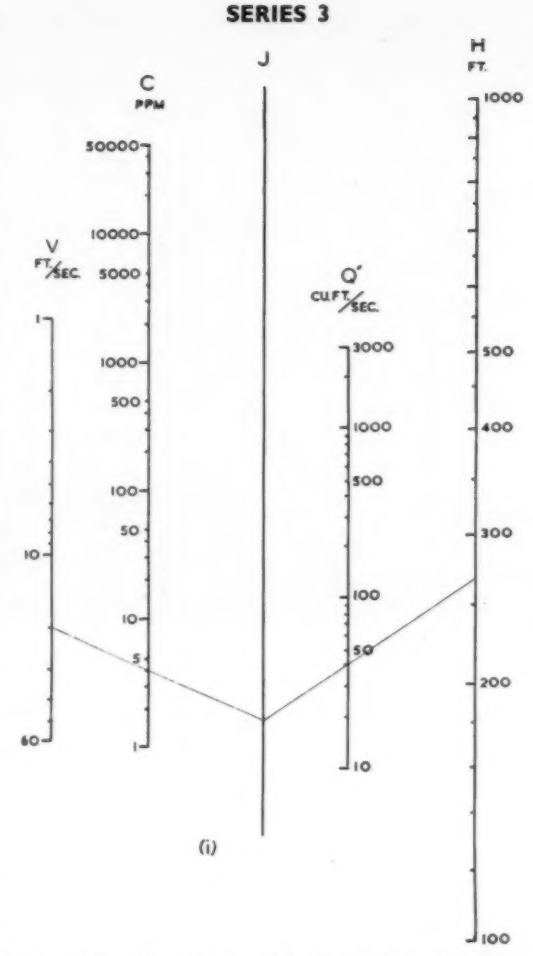

(ii) ambient atmospheric conditions are 15° C (59°F);
(iii) the temperature inversion in the atmosphere is +6°C per 1000 ft rise in height.

Using the Nomograms

(A) The height of the stack, H_s, is either known, or assumed at some reasonable value. The top of the stack must be well clear of surrounding buildings. The stack exit diameter determines the velocity of the issuing gases.

(B) The value of H_v is found from the nomograms, series 1, based on Equation (2), as follows:

A value of K_1 $(= 1 + 0.43\ v/u)$ is found from 1 (i). K_1 is then located on the K_1 scale in 1 (ii), and with the value of v a point found on the reference line J_1. This, combined with a value of u, locates a point on reference line J_2, which, when combined with Q, gives the value of H_v required.

(C) The value of H_T is found from the nomogram series 2.

A value of $K_2\left(=1-\dfrac{0.28\,T_1}{g\,.\,0.43}\sqrt{\dfrac{g\,G}{T_1}}\,.\,\dfrac{u}{\triangle}\right)$

$(=1-0.151\ u/\triangle)$ is found from 2 (i) and located on 2 (ii). On 2 (ii) the point on the K_2 scale is combined with u to give a point on the reference line J_1. This, combined with a value of Q, gives a point on the reference line J_2. This point is combined with a value on the v scale, and the value of Z read off the Z scale. The value of Z is located on the Z scale in 2 (iii), joined to v, and a point located on the reference line J_3. This is combined with a value of $\triangle$ to give a point on the reference line J_4, which, when joined to Q, gives the value of H_T.

(D) H is then found by the summation of H_s, H_v and H_T.

(E) The maximum concentration of gases at ground level, or of airborne particulate matter, which occurs about 10 to 15 stack heights away from the stack in the downwind direction may be found from series 3.

A value for H is joined to Q' (the quantity emitted per unit time) to give a point on the reference line J, which, when combined with the value of v, gives the required value of the concentration C.

If the quantity of the gas emitted, Q' is in cu. ft/sec., then C will be in parts per million. In calculations for particulate matter, Q' is kg/sec., the calculation will give C in mg per cu. ft. Dividing mg per cu. ft by 64.8 gives grains per cu. ft; also, 1 grain per cu. ft is equal to 2.3 g per cu. m.

Example

A 200-ft stacks emits hot gases, containing 5% SO_2 at a rate of 800 cu. ft/sec. (at ambient conditions). The exit velocity of the gases from the stack is 20 ft/sec., and their temperature is 100°C above ambient. The wind velocity is 20 ft/sec. (13.6 mph).

From series 1, $H_v = 22$ ft.
From series 2, $H_T = 42$ ft.
Therefore, $H = 200 + 22 + 42 = 264$ ft.
And from series 3, $C = 4.0$ parts per million, by volume.

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66.074.6: 614.71

CONTROL OF FLUORIDE AIR-POLLUTANTS*

Injection of pulverised hydrated lime followed by dust removal adopted at U.S. steelworks

IN January, 1951, the Geneva-works Mill of United States Steel Corp., Utah, was told by the Utah State Agricultural College that chronic fluorine poisoning of animals had been discovered near their plant.

Consultations with experts in air pollution enabled acceptable standards for testing and analytical determinations to be developed and a programme of determining the source and concentrations of fluorides was started promptly. A preliminary plant survey was conducted in March, 1951, and the results indicated that the open-hearth shop and the sintering plant were the only major sources of the contaminant that would require corrective measures, and also that the raw material responsible for the greatest quantity of fluorine was the iron ore which is mined in Southern Utah near Cedar City. The Stanford Research Institute conducted in-plant balance of fluorides entering the plant in raw materials, leaving the processes in finished product or wastes and being emitted to the atmosphere, and, at the same time Geneva's engineering department concentrated on testing and evaluating various processes and types of gas cleaning equipment which might prove effective for the problem. Tests conducted on a pilot-plant scrubbing tower of 3000 cfm capacity failed to indicate that desired fluorine removal performance could be attained by this method. Moreover the results proved that a once-through scrubbing system would require an excessive volume of water which in turn would introduce a stream pollution problem. The water recirculation tests introduced a serious corrosion problem due to the low *pH* characteristics of the effluent. When alkaline additions were made to the water, deposits of calcium solids in the spray towers were so severe the equipment had to be shut down regularly for cleaning.

Since the fluorides existed in the waste gas streams in both the gaseous and particulate state, the application of the principles of dry dust separation was not a simple answer to the fluorine collection problem. There had to be an intermediate step in the gas cleaning process and this step was the conversion of the gaseous fluorides to solids, a form in which they could be separated from the gas stream by dry methods. A dry-type electrostatic precipitator as a dust separation unit was installed in series with the tower previously used as the gas scrubber to utilise the tower capacity for residence time for chemical reaction.

Pilot plant work determined that finely pulverised limestone or calcium hydroxide had an affinity for the gaseous fluorides when injected and allowed to diffuse in the gas stream. About six times the theoretical amount was required for satisfactory conversion of the gaseous fluorides it was found since in a dry state the rate of reaction is a function of surface area of the reactant.

Reduction at Source

Simultaneously, efforts to reduce the emission of fluorine at the source progressed. It was found that limestone could be added to the mix at a rate as high as 6% by weight of the mix without creating any serious problems in the sintering process. At this maximum, nearly half of the fluorides previously driven off during the sintering process was fixed in the product and, therefore, never reached the atmosphere. The practice of adding limestone to the mix was adopted immediately.

As it had been found that the sintering plant fluoride emanations exceeded those from the open hearth, that plant was the first to be provided with corrective equipment. A contract was placed with Research Cottrell Inc., New Jersey, for a gas treating and cleaning system in March, 1953. They supplied two identical and independent units designed to treat the waste gases from the two sintering machines and the process employed were very similar to those studied in pilot plant work with the exception of a waste-gas recycle principle.

Each sintering machine consists of a travelling chain of grates on which is distributed a layer of sinter mix consisting or iron ore fines, coke breeze and limestone. In use, as the flame front travels through the porous bed, the fines are agglomerated into a clinker-like mass which is suitable for charging into the blast furnaces. At the first point in the waste gas system where chemical conversion of gaseous fluorides takes place, hydrated lime ($Ca(OH)_2$) is injected into the stream at a rate of 5 lb. a minute. The hydrated lime is fine enough to pass through the primary cyclone collectors. Virtually all dust exceeding 44 μ in size is removed by these primary cyclones, and, therefore, the gases continuing on to the final treatment units have relatively constant characteristics. The gases are sufficiently rich in oxygen to support combustion of the sintering fuel; therefore, about 40% of the fan discharge can be recycled back over the sinter bed. This principle reduces the volume of gases requiring final treatment and cleaning, thus cutting by 40% the capacity of the equipment that would otherwise be required.

Final Treatment of Sinter Gases

The final treatment and cleaning section of the system consists of facilities for furnishing and injecting pulverised limestone for final conversion as well as the final dust separation equipment consisting of a battery of mechanical cyclones and an electrostatic precipitator. Limestone is reduced to a dust by ball-mill pulverisers and is injected at

* *Abstract of a paper read by W. T. Purvance, U.S. Steel Corp., at the September meeting of the American Institute of Chemical Engineers, Salt Lake City.*

a rate of 30 lb. per minute into the gas stream at a point just downstream from the recycle junction. The fineness to which this reactant material is pulverised is 80% passing a 200 mesh screen; therefore, maximum surface area is made available for exposure to and absorption of gaseous fluorides. After the reactant material has been introduced into the gas stream, the stream is directed to a treatment chamber which is designed to produce maximum contact between gaseous fluorides and the reactant limestone. Included in this chamber is a battery of 56 cyclone separators which separate the more coarse particles of dust from the gas stream prior to its entry into the electrostatic field for final cleaning. The cyclones also function as a mixing device which greatly increases exposure of fluorides to the reactant material surfaces. Dusts, too fine for mechanical separation, are separated from the gas stream by the electrostatic precipitators and the clean gases are allowed to enter the atmosphere through the exhaust stacks. This was the first installation of its kind ever erected and the largest single electrical precipitator unit known to have been erected for collection of such material.

Open Hearth Problem

While the erection of the gas cleaning equipment was in progress at the sintering plant, further studies to obtain design data and to determine the application of gas cleaning equipment at the open hearth shop were conducted. A dry-type chemical reaction was again indicated with material high in calcium content. The final dust separation equipment, it was found, would have to be a highly efficient type of cleaner and yet offer a relatively low resistance to the flow of waste gases. The equipment meeting the specifications was an electrostatic precipitator.

Through testing and sampling it was found that during the normal processing of a heat of approximately 250 tons of steel, the waste gas volumetric flow rate varies between 18,000 and 60,000 scfm per furnace. Even though it appeared that the installation could be sized to accommodate a shop flow rate of 316,000 scfm, it was decided for safety to size it to process a flow rate of 420,000 scfm.

From determinations through hundreds of basic heats, the average shop dust concentration was determined to be 0.5 grain per scf. Having been able to determine average gas volumes, average dust loadings, average heat and average moisture, it was decided to collect and blend the waste gas effluent from all ten furnaces in order to supply a gas feed to the recovery portion of the system with a degree of uniformity necessary to maintain over-all level performance.

Blending of waste gases is accomplished at the Geneva installation by the use of a collector main flue, through which all the gases pass in their flow to the eight treatment units.

Two Systems Compared

The two basic differences between the systems for the sinter plants and the open hearth furnaces are the pressure under which they operate and the material which is used as a reactant. The open hearth units are exhausted by induced draught fans which place the treatment unit chambers under a negative pressure. The material used for the chemical reaction is hydrated lime ($Ca(OH)_2$) a compound having a higher available calcium content than the limestone used as the sintering plant. The induced draught fans discharge the clean gases into the existing stacks where they are then exhausted to the atmosphere. As there are ten furnaces and stacks and only eight precipitators, a small bleeder line is used to carry a portion of the discharge gas from the two end precipitators to the two end stacks.

One of the major engineering problems encountered is that of handling and disposing of the dust from the open hearths that is collected by the cleaning unit. Open hearth fume is composed primarily of particles below 5 μ and about 40 to 90 tons of the combined reactant and open hearth dust is collected from the ten-furnace shop in a 24-hour period. At the installation the dust is removed from the precipitator hoppers by a pneumatic system which conveys it to two central points of storage. The dust is stored in elevated silos and as the silos fill, it is allowed to flow by gravity into a reject mixer where it is combined with sufficient water to render it "dustless". The material flows from the mill into a truck by which it is carried to the dump area for final disposal.

Another major problem is the control of moisture content in the gas. The value must be maintained sufficiently high to assure desired precipitator efficiency and yet not affect the collected dust to the extent the material handling system will not function satisfactorily. In practice the moisture is adjusted with low pressure steam as cold-water spraying causes deposition on the fluewalls.

A third problem is furnace pressure control. It is important to provide an open hearth cleaning installation with properly-sized fans and controls that will regulate gas flow and system pressures (and, hence, temperatures) to within extremely fine tolerances. For example, the pressure just below the roof of a furnace must not vary more than a few hundredths of an inch of water for any length of time or rapid deterioration of the roof refractories will be encountered.

The systems which have been adopted require throughout diligent operating attendance and continuous monitoring to assure that their operating function is maintained continuously. The "extremely high costs" associated with the research initial equipment, and operating costs involved must be considered as a previously unrecognised cost of using Utah iron ore.

FALL OUT AND DEPOSITION OF SOLID MATERIALS EMITTED BY TALL CHIMNEYS

(see opposite page)

FOR PARTICLES with STOKES' diameters of 20 microns or less, the equation given by NONHEBEL and HAWKINS, *J. Inst. Fuel*, 1955, **28**, 530, based on BOSANQUET, CAREY and HALTON, *Proc. Inst. Mech. Eng.*, 1950, **162**, 355, may be used. The deposition, T, in tons mile^{-2} month^{-1} is:

$$T = 1.14 \times 10^9 \frac{\Sigma b}{v H^2}$$

Where $\Sigma = Q'_1 f_1 + Q'_2 f_2 + Q'_3 f_3 + \ldots + Q'_n f_n$, the subscripts referring to the classification of material;
Q' = the solid material emitted in lb./sec.;
f = the falling speed of the particles (ft/sec.) (which can be obtained from the nomogram method by R. JOTTRAND, *Brit. Chem. Eng.*, 1958, **3**, 3, 143;
b = the proportion of time the wind is in a 45 degree sector; and
v and H = the wind velocity and the equivalent stack height (see p. 620).

EXAMPLE

A 200-ft stack emits hot gases, containing 1.33 lb of Fe_2O_3 fume a sec. at a rate of 800 cu. ft/sec. (at ambient conditions). The exit velocity of the gases from the stack is 20 ft/sec. and their temperature is 100°C above ambient. The wind velocity is 20 ft/sec.

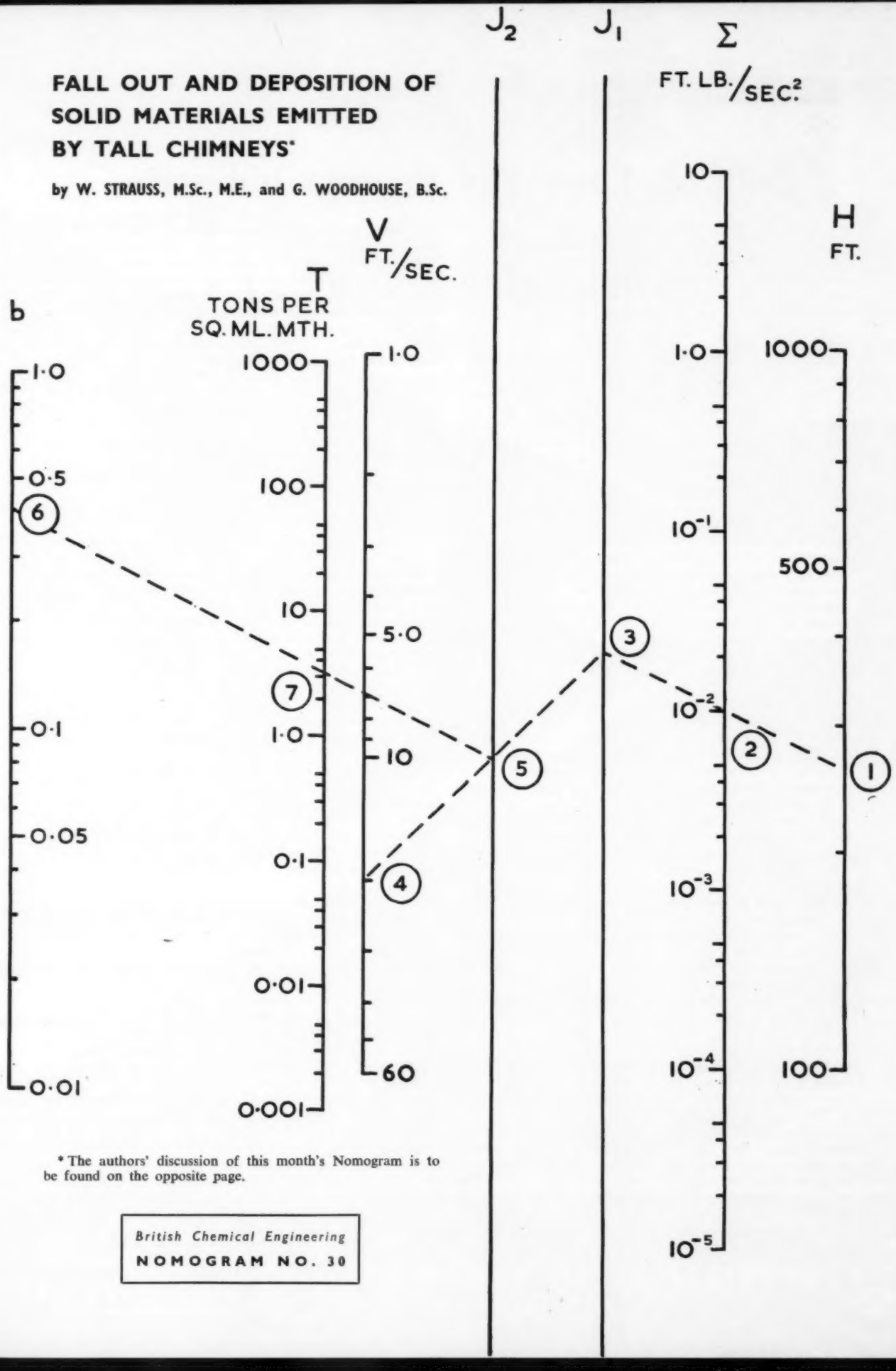
From the previous example (see p. 620), the equivalent stack height is 264 ft. The table gives the particle distribution of a typical Fe_2O_3 fume.

Particles (dia. in microns)	Q' lb./sec.	f ft/sec.	$Q'f$ ft lb./sec.^{2}
>10	0.027	2.10^{-1}	0.0054
10-5	0.067	3.10^{-3}	0.00201
5-1	0.505	5.10^{-3}	0.00252
<1	0.73	2.10^{-4}	0.00015
			$\Sigma = 0.01008$

Then T = 3.2 tons mile^{-2} month^{-1} at the point of maximum deposition, which is about 10 to 15 equivalent stack heights from the stack, in the direction considered.

FALL OUT AND DEPOSITION OF SOLID MATERIALS EMITTED BY TALL CHIMNEYS*

by W. STRAUSS, M.Sc., M.E., and G. WOODHOUSE, B.Sc.



* The authors' discussion of this month's Nomogram is to be found on the opposite page.

British Chemical Engineering
NOMOGRAM NO. 30

AMERICAN LETTER

Politics, Laws and Process Industries

RECENT political and legal developments have caused a considerable stir in many American process industries. These activities range from territorial expansion promising new raw material sources and increased markets, to restrictive rulings affecting company policies, and even the rights of the individual employee.

Anti-Trust Activities

Whether stimulated by the belief in increased competition as a means of combating the U.S. recession, or simply by professional zeal, the Anti-Trust Division of the Department of Justice under Mr. Victor Hansen has been extremely active in recent months. The polio-vaccine makers have been accused of fixing prices and making excessive profits, the Du Pont company has been in trouble over vested interests and the Pfizer company has been the subject of investigations concerning alleged monopolies in the citric acid field. A further case against the chemical and drug industry was lodged in August this year, when five of the biggest U.S. makers of antibiotics were accused of collusion and of manipulating a Pfizer tetra-cycline patent, so as to restrict access by other manufacturers in order to maintain high prices. It is understood that part of the Federal Trade Commission's case is based on the maintenance of high prices for the newer drugs, whereas the price of older antibiotics has fallen considerably. A stiff legal battle is likely to ensue later this year, and the outcome will be interesting. According to some people, the increased activity of the Anti-Trust Division is not only to curtail large-scale price fixing, but also arises from a desire to protect and foster proper research. Otherwise, it is feared, the extension of monopolies, patent abuses and the sub-division of the chemical industry into ever-narrowing fields may lead to research only being undertaken in projects offering the highest profit, or the most immediate gain, to the detriment of the Nation.

An unusual anti-trust suit was recently brought against the Monsanto Chemical Company, as a result of selling the rights of certain detergent sales to the Lever Company. The Anti-Trust Division contended that this transaction came under the Clayton Act which forbids anti-competitive mergers, since the deal left the field largely to one seller, even though no product was taken off the market. Furthermore, similar deals between other manufacturers might be encouraged, thus reducing competition in this industry to an even greater degree. The Government, it is believed, wishes to have the original Monsanto rights transferred to a third party, so as to promote competition, but this may prove rather difficult to implement.

A Ruling on Trade Secrets

A great deal of interest has been displayed in the action brought by Monsanto to restrain a former employee, Charles Miller, and others, from using trade secrets applied to the phosphorus industry. In the action heard at Salt Lake City, Judge Christenson ordered the return to Monsanto of more than 100 documents said to be appropriated by Miller and permanently enjoined the defendant from using trade secrets acquired when with Monsanto. This decision upheld the employee agreement of the company, but, the Judge pointed out, even without such an agreement, an employee is still bound under common law not to reveal trade secrets, whether carried on paper, or in the mind. This important decision is likely to promote much future discussion, and possible litigation as well.

A surprising ending to another trade secrets case also occurred recently. This was the action between the National Cylinder Gas Co. and nine former employees charged with using confidential details concerning catalysts, as the basis of a new company. Under the ægis of the Court, a settlement was made whereby a guaranteed $500,000 will be paid to the National Cylinder Gas Co. by the new Company, Catalysts & Chemicals Inc. In return, the new Company will have rights to use information obtained prior to 1957 and will licence National Cylinder Gas to manufacture and sell catalysts developed by Catalysts & Chemicals, prior to the end of 1959. In addition, all ethical charges have been dropped by the plaintiff.

The 49 State

The incorporation of Alaska as the 49 State adds another 20% of area and untold weath to the Union. Furthermore, as a State, Alaska can now lease land with insistence that satisfactory exploitation be carried out. Formerly, as a territory, only a bare minimum of assessment activity was required on the part of the leaseholder. This change should lead to greatly accelerated developments in the mining and process industries of this vast region, as well as the flow of new capital. Although Alaska is not, as sometimes supposed, an impenetrable snow-bound domain, distance and climate do give rise to increased operating costs. This has been realised by the Government and several inducements have been offered to investors, to offset these extra burdens. An Incentive Act provides tax-free operation for 10 years to new enterprises not in direct competition with existing concerns.

Much of the native wealth of Alaska is still speculative, but is tremendously attractive to mining and process interests. Typical known assets include 17 million KW of hydro-electric power, over 100 billion (U.S.) tons of bituminous coal, large reserves of anthracite and iron ore, and virtually every commercial mineral and metal, including gold and uranium.

The St. Lawrence Seaway Controversy

Another example of related Federal, State and industrial interests is the jurisdiction over the St. Lawrence Seaway. Scheduled to be in full operation by April 1959, the International Rapids section was opened to large vessels in July 1958, and supervision of U.S. interests was unexpectedly transferred from the Defense Department to the Commerce Department. This has been viewed with alarm by several State and industrial concerns in the Mid-West, who feel that the Commerce Department might be influenced by rival organisations to raise the Seaway toll charges to prohibitive levels. This would stifle the future prosperity and development of those Mid-Western and North-Eastern areas who will use the canal, particularly future suppliers and consumers of bulk chemicals and raw materials. However, the Canadian Government will also be involved in determining the international toll rates to be used, and in the interests of Canadian prosperity, it is anticipated that reasonable rates will eventually be set. Meanwhile, some uncertainty continues; apparently political factors prove to be more difficult to surmount than the complex engineering problems of this great enterprise.

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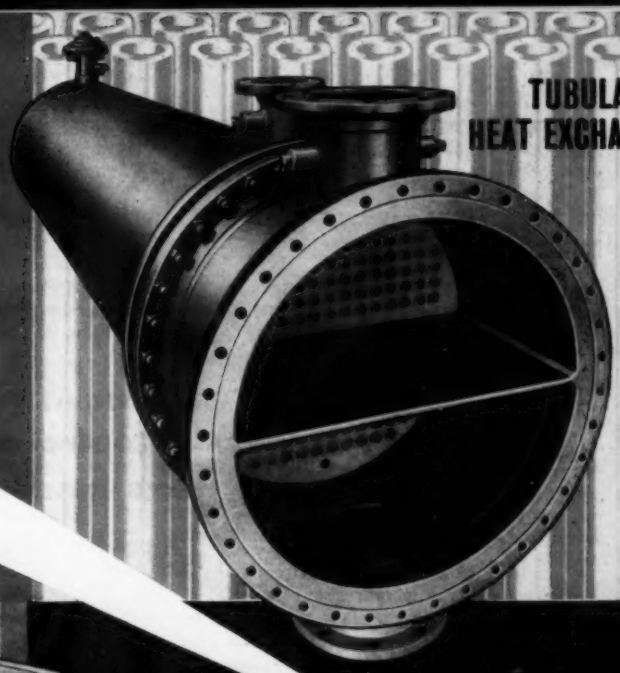
Research
Manufacture



TUBULAR
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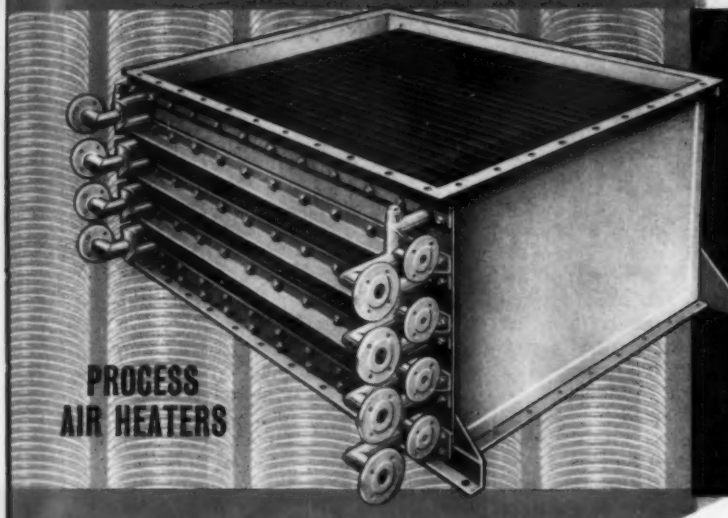

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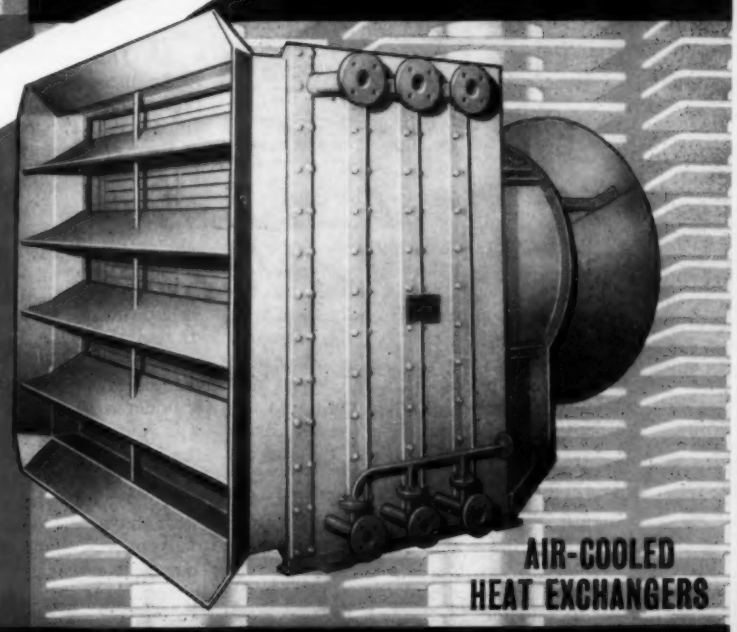

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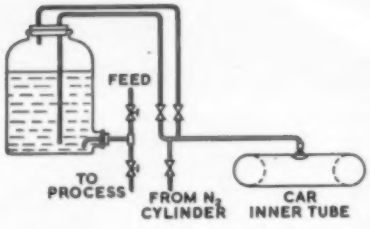
PROCESS ENGINEER'S NOTEBOOK

Feeder Uses Automobile Inner Tube

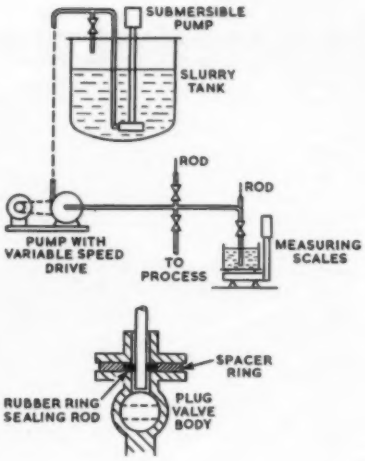
THIS ARRANGEMENT was devised originally to handle an extremely toxic and inflammable reagent which had to be fed at a constant rate to a small 20-gal. reaction vessel. The feed vessel, a stoneware 1-gal. capacity container, works on the Mariotte tube principle, but both the vent provided for allowing air to escape during filling and the air-bleed connection are piped to a car inner tube from which the Schrader valve has been removed. Small pinch valves are provided in each of the two lines. In addition, another connection, also with a valve, is provided and this is connected to an inert gas supply, which in this case is a nitrogen cylinder.



First the feed vessel is filled with a fluid innocuous to the reagent which is run out slowly by means of the lower valve at the draw-off connection. The inert gas is sucked into the vessel from the main tube, which is already mildly inflated with nitrogen. By opening the vent valve, nitrogen is allowed to pass into the vessel and fills it completely when the liquid has been discharged. The vessel drain valve is then closed and the reagent (contained in cylinders) is run into the vessel through the feed valve; the nitrogen is displaced back into the inner tube while the filling is taking place. When this is complete the vent valve is closed and the valve on the dip-pipeline is opened to the inner tube. The liquid may then be discharged under a constant head to the process.

Control of Small Flow Rate for Slurries

A DIFFICULT PROBLEM which arises with slurries is the control of low rates of flow. Restricting the flow to the required rate by means of valves is not always reliable, as they may block, especially when the rates of flow are very low. One method which has been used successfully consists in pumping the slurry against the controlled back-pressure set up by another pump working in the reverse direction. In the accompanying sketch, slurry is fed by means of a submersible pump to process and a proportion of the flow is returned to the vessel to maintain the solids in suspension. The discharge is then fed into the discharge of another centrifugal pump driven by means of a variable-speed drive. Although flowmeters have been adapted for measuring flow rates of slurries, in this case the flow was measured by means of a branch which diverted the flow to a container resting on a set of platform scales. This enabled the rate of flow to be measured directly, the desired rate being found by trial and error. Once found, the variable-speed setting of the back-pressure pump can be left



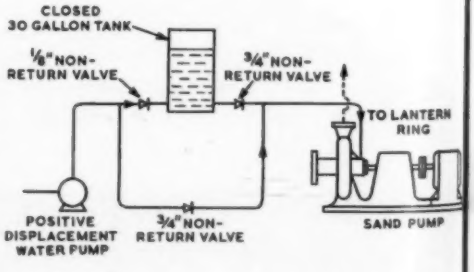
for a considerable time without further adjustment.

The valves used in this circuit were of the lubricated plug type and to remove quickly any blockages caused by solids settling out when one or other of them was closed, the rodding arrangement illustrated was fitted. For example, by opening the upper valve and pushing downwards through the open valve on the process line, it was quite an easy matter to clear away material deposits at that point. The O-ring seal was sufficient to prevent serious leakage past the rod.

For Pumps Handling Slurries

WHEN SLURRIES are pumped it is by no means unusual for the solids to find their way to the pump gland and cause it to leak badly. With many designs of centrifugal pump the gland is under suction during operation, and it is when the pump is shut down that the head of the liquid left in the discharge pipework causes the slurry to be forced into the gland. Mechanical seals have successfully replaced the conventional gland in some instances, but their use is not always the complete answer. The layout shown in the accompanying diagram was devised by the Denver Co., and gets over the difficulty by feeding water to the pump gland during operation and while the pump is shut down as well.

The tank is a closed one and is fitted with an $\frac{1}{8}$-in non-return valve at its feed connection and a $\frac{3}{4}$-in. one



at the discharge connection. The tank is by-passed by a loop, in which is fitted another ¼-in. check valve. The small positive-displacement pump has an output of 10 gpm. The check valves at the tank inlet and in the loop open when the pumps are running, whereas the valve at the tank discharge closes. The small check valve allows a bleed of sealing water to pass into the tank until the pressure of the air trapped in the tank is equal to the pressure in the main sealing water line.

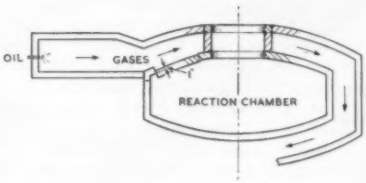
The electrical connections are so arranged that when the centrifugal pump is shut down the positive-displacement pump stops also. The pressure in the main sealing water line then drops, with the result that the tank-inlet check valve closes along with the valve in the loop. The check valve on the tank discharge opens and water from the tank under the residual line pressure is forced to the centrifugal pump gland. The pressure of this water will fall gradually, but not before the contents of the discharge line have returned to the pump sump.

An Interesting Improvisation

WORKS ENGINEERING DEPARTMENTS are sometimes asked to carry out repairs by improvisation, usually because delay would cause serious financial loss, and correct materials are unobtainable at short notice. Such occasions demand not only the fullest use of basic engineering knowledge, but also a talent difficult to define other than as the ability to view a problem without blinkers. To a greater or lesser degree, this should be developed in all members of such departments, as major improvisation problems also demand a team approach if the repairs are to be completely successful. This can be illustrated by a description of a repair carried out recently by the department controlled by the author, on a Bethlehem-type furnace with a hearth diameter of 14 ft, producing hydrochloric acid and sodium sulphate. A section through the furnace is shown schematically in the accompanying diagram. Hot gases from the combustion of oil pass round the outside of the reaction chamber, temperatures in the zone nearest the combustion chamber being in the region of 1000°C. The furnace operates continuously 24 hr a day for 50 weeks of the year.

The roof of the reaction chamber was built of specially shaped "Carbofrax" bricks purchased from America in 1942. No spares were carried, the arch seemingly maintaining its shape well until 1956. The bricks were tapered in two planes and radiused in the third, and the shapes altered in dimension in relation to their distance from the centre of the furnace. In the latter quarter of 1956, outward movement of the skewbacks supporting the inner arch at the throat of the combustion chamber caused a slip in the brickwork of the arch, and a sector comprising one-fifth of the roof was found only to have 1 in. interference on its outer radius. It was decided to shut down for repairs to be carried out, as total collapse was possible, and efficient operation of the furnace was difficult due to leakage through the defective joints. Sales of the products were buoyant, and the engineering department were asked to carry out repairs in the shortest possible time.

Forms were erected inside the reaction chamber and the roof sector involved was carefully dismantled. During the dismantling, several bricks were accidentally broken, and a number were found to be so badly cracked that they could not be reused because of dimensional increases. It was therefore decided to manufacture replacements in the works, using an equivalent silicon carbide ramming material. Twenty-seven bricks were required. Moulds were made from 1 in. timber with screwed and clamped joints. We were assured by The Carborundum Co. Ltd., that there was no need for any expansion or contraction allowance, as movement of the material would be negligible.



"Carbofrax" No. 3 ramming material was carefully mixed with water in the proportions of 1 cwt of dry material to five pints of water, and rammed into the moulds using a hardwood ramming tool of 2 in. × 2 in. cross-section. Great care was taken to ensure that the ramming was even and that there was good bonding throughout. When ramming was completed, the bricks were carefully removed from the moulds by removing the clamps and screws. They were then air dried for 12 hr at 60°F and 6 hr at 90°F.

An oil-fired, lift-out crucible furnace was used for firing. It was fortunate that such a furnace was available in the works, in view of the firing temperature necessary. The bricks were stacked on edge in chequer work fashion to ensure even heating and good combustion of the oil, ten bricks being fired at a time. The furnace was warmed up by gas for approximately 1 hr., the oil burner was then ignited, and the temperature of the bricks was gradually taken up to 1200°C, Seger cones being used for temperature indication. This temperature having been reached (in 4 hr), the furnace was shut down, and allowed to cool for 12 hr with covers on. The bricks were removed from the furnace and cooled at 90°F. for a further 8 hr before being fitted.

"ALFRAX" high-alumina cement was used for jointing, in view of the acid conditions of the furnace. It was not possible to lay the last brick due to dimensional differences; the hole was therefore rammed *in situ*. The furnace was slowly brought up to temperature and recommissioned within a week of being shut-down. Inspection in March 1958 showed no deterioration of the rammed bricks, and the operation can therefore be regarded as successful.

From the commencement of the shut-down all members of the department were encouraged to take an interest in this problem, and our success is entirely due to the teamwork and intelligence inspired by this approach to a difficult repair job.

R. A. DUCKWORTH
Works Engineer,
F. W. BERK & CO. LTD.,
Stratford, London, England.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Chemical Development in China

Among the many developments in the chemical field recently announced in China is the commissioning in Nanking of a phosphorus-ore producing plant having an annual capacity of 300,000 tons of concentrated ore. The product is to be used for various phosphate fertilisers. Other developments include the start of building in Taiyuan, Shansi province, of a plant to produce annually 49,000 tons of high-polymer insecticides and plant hormones. It has been announced also that the Huhehot Chemical Works in Inner Mongolia, which is due to start production in 1959, will have an annual output of 1500 tons of PVC and 10,000 tons of other products, including caustic soda, trichlorethylene, hydrochloric acid, bleaching powder and calcium carbide. New factories in the country's pharmaceutical industry include a plant for extracting liquorice and an aureomycin plant and an ephedrine plant. Trial production of the following drugs has already been made in the country: scarlet fever antitoxin, encephalitis vaccine and concentrated heat-resistant small-pox vaccine.

Developments have been taking place also in the production of chemical equipment. The Hsincheng and Hsinhsin instruments and meters plants in Shanghai have been amalgamated and the new organisation is due to produce 34,000 sets of thermo-technical equipment yearly for measuring pressure, flow and temperature in addition to other control instruments. The manufacture of China's first 2400-hp high-pressure gas compressors for ammonia synthesis has been announced. The machine is said to have an hourly capacity of 7800 cu. m. of compressed nitrogen and is suitable for a synthetic ammonia factory having an annual capacity of 50,000 tons of nitrogenous fertiliser. Serial production of the machine is to begin in North-east China.

Petroleum Refining

A refinery designed to treat Sahara crude oil and having a caapcity of about 2 million tons a year is to be built by a newly-formed company near Algiers "as soon as possible". The installation will produce sufficient petroleum products to meet Algerian needs and the excess will be available for export. The following organisations will participate in the company: Beryl Algérie, Compagnie Française des Petroles, Compagnie Française de Raffinage, Mobiloil Française, Société Française des Petroles BP, Société Shell d'Algérie, and Standard Oil (New Jersey).

A medium-pressure hydrogenation process will be used in a plant being designed by the Chinese Fushun Petroleum Institute for the large-scale production of petroleum products from bituminous coal tar. The method, the Chinese Academy of Science claims, will produce 7 tons of phenol, 35 tons of petrol and tractor oil and 11 tons of diesel oil from 100 tons of the raw material.

Deutsch Erdol A.G. are erecting in Germany a plant for the extraction of pure propylene. It is expected to be commissioned by the end of 1958.

Canadian Gas Consumption

At June 30 this year 713,732 consumers in Canada were using natural gas as compared with 584,211 at the same date in 1957, while the number of manufactured gas customers in the year declined to 276,296 from 325,390. Industrial customers of natural gas increased from 3391 to 4391 but industrial users of manufactured gas declined to 523 from 734. In the first six months of the current year sales of natural gas rose to 109,139 million cu. ft from 95,670 million cu. ft in the comparable 1957 period. Revenue from sales in all categories totalled $61.7 million in the six months ended June 30, against $47.5 million in the corresponding 1957 period.

Alkali Production

The 40 million pesos (£11 million) caustic soda plant of Sosa de Mexico, at Monterrey, was commissioned recently. It has an estimated annual capacity of 6000 tons of caustic soda, 5000 tons of liquid chlorine, 2000 tons of hydrochloric acid and 1000 tons of sodium hypochlorite in addition to certain quantities of carbon tetrachloride and chloroform. It is expected that Mexico will now be self-supporting in caustic soda.

Unexpectedly large quantities of potash have been found in samples obtained from oil borings in Jutland, and a committee has been set up to study the possibility of mining it.

High-temperature Polymers

The United States Air Force has awarded a contract for the study of high-temperature inorganic polymers and the chemistry of new solid rocket propellent components to the United States Borax Research Corp., Anaheim, California. The contract, which will be carried out in co-operation with the Materials Laboratory of the Wright Air Development Centre, is in support of research on inorganic polymers and plastics, resulting from the requirement for new materials that will withstand temperatures of 1000°F.

New French Rubber Plant

The first plant in France for the manufacture of styrene-butadiene rubber is to be built at Berre, near Marseilles. Three companies will be concerned in the development, Shell St. Gobain (in which the Royal Dutch/Shell group of companies has a 60% interest), Michelin and Cabot-Texas Butadiene.

The plant will have a capacity of 50,000 tons per year and will draw its raw materials from the neighbouring Shell Berre refinery, the St. Gobain chemical plant and the Cabot carbon black plant. Production is expected to begin in 1961.

Lonza A.G.

The 61 annual report of Lonza A.G., Switzerland, showed that total turnover for the last financial year increased by 10%. Some 250,000 tons of products were sold, of which 17½% were "new" chemical products (these accounted for 50% of total value). Sales of nitrogen fertilisers and technical nitrogen products, mostly to the home market, were about the same as in the previous year. Organic basic products sales were also about the same level as previously, but increased sales were recorded in organic intermediate products and in plastics. The net profit increased slightly from Sw. frs. 5.6 million.

Italian Paper Mill

Italy's largest single paper mill, the Cartiera del Timavo, is nearing completion and has already started production. It is situated a few miles from Trieste and is stated to be equipped with the largest paper-making machine in Italy and one of the largest in Europe. The machine, which was imported from Finland, can produce 1900 ft of newsprint a minute. It is equipped with a high degree of automation and required an investment of £3 million.

French Seaweed Development

The Société Nourylande, at Venette, has developed, on a semi-industrial scale, the manufacture of mannitol from seaweed. Production at present is about 50 kilos per day, but the company plan to increase it to several tons per month to meet amply the French demand.

Chemicals

A new starch factory with a capital of 4 million pesos (£1.1 million) has just been opened in Mexico by Industrial Aranguran. During 1957 production of sulphuric acid in the country rose to 246,984 tons and consumption to 247,721 tons. Imports of the acid over the past few years have been negligible. Latest figures for alcohol show that production has risen to 44,300 tons annually, but has not kept pace with consumption and certain quantities have to be imported.

Carbon Black Plant

The Société d'Electrochimie, d'Electrométallurgie et des Aciéies Electriques d'Ugine has comissioned at is works at Villers-Saint-Sépulchre, France, a plant for the preparation of carbon black employing the process developed by the Société des Produits Azotés. The capacity at present is 6000 tons yearly.

British Phthalate Plant

New plant for the manufacture of phthalate plasticers at the Widnes plant of A. Boake, Roberts & Co. Ltd. is expected to be soon capable of operating at its full output. It has so far produced "useful tonnages of saleable products of high quality".

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Book Reviews

Petroleum Refinery Engineering—Fourth Edition

by W. L. Nelson

McGraw-Hill, London, 1958, 960 pp., 116s. 6d.

THE value of a book of this type depends mainly on the comprehensiveness with which it covers the subject and on the extent that the information it presents does not become out of date. Regular revision is, therefore, essential and this latest edition is especially welcome in view of the continued development and expansion in petroleum refining. DR. NELSON has, in this new edition as in earlier ones, interpreted engineering in its widest sense. Besides the design of refinery equipment he deals fully with the processes employed in petroleum refining and the laboratory examination and evaluation of crude petroleum oils and the products therefrom.

While no new chapters have been introduced, a major change which should greatly enhance the book's usefulness to chemical engineers and petroleum technologists outside the United States is the inclusion of much more information on the nature and the processing of Middle East crudes. International interests are further recognised in a greatly extended chapter on crude-oil evaluation and an Appendix outlining the analyses of over 160 crudes from the world's major oil fields. The classification of crudes in this Appendix is however a little inconvenient as it is according to API gravity and any particular crude is not easily located by name if this peculiarly American property is unknown to the searcher.

The major work of revision has, however, been the bringing up to date of each chapter and the re-organisation of some of the subject matter. The most recent references quoted date from 1956, but such a gap is probably inevitable in the publishing of a work of this magnitude. The chapter on refinery products now includes specifications for all the more recently developed ones, such as jet and rocket fuels as well as for modern gasolines, diesel fuels, etc. These specifications, however, relate mostly to North American market requirements. The following chapter is an excellent guide to the evaluation of the very wide range of crude oils now available to refiners, and includes some essentially practical correlations for predicting the properties of products. Fundamental physical data on petroleum follows and this leads into chapters dealing with the operation and performance of refinery processes, interspersed from Chapters 13 to 18 with a section dealing with fundamental process design.

While retaining most of the information on the older established processes, new additions are sections on catalytic reforming and catalytic desulphurisation; catalytic cracking is also dealt with adequately in the light of the latest refinements and developments. The performance of each process is well described and supported with commercial operating data. The chapter on thermal cracking processes, which have by no means been completely displaced by catalytic ones, has been considerably expanded and now includes such new developments as the fluidised coking process. Again it may be remarked that consideration is given only to the North American situation.

Turning to the design section, the essential fundamental design data on fluid flow, combustion, vaporisation, fractionation, heat exchange and heaters from the third edition are retained and supplemented by information on modern practice. Transfer rates given for tube-stills have been increased to bring them into line with present-day standards while the chapter on heat exchangers has been improved by the inclusion of charts relating pressure drop and transfer rates and for the simple derivation of transfer rates and fouling factors. It is surprising that although enthalpy charts are illustrated in Chapter 5, no guide to their use in calculating heat balances is given, the author preferring to use specific and latent heats in all his worked examples.

The concluding chapters comprise an excellent survey of refinery economics and the same useful fully worked example of a tube-still topping plant design as in earlier editions. Noticeable omissions are the author index, which appeared for the first time in the third edition, and the references at the end of each chapter. These reference lists were undoubtedly becoming unwieldy, and the page footnotes now provided should prove adequate. Altogether, this latest revision has consolidated and improved the book thus enabling it to retain its place as an invaluable work of reference for the petroleum and allied industries.

H. T. PORTER

Biochemical Engineering

Edited by R. Steel

Heywood & Co. Ltd., London, 1958, 328 pp., 50s.

THIS is an expanded version of a course of ten lectures given at the Manchester College of Science and Technology, and therefore shows variety of style, and some overlapping. It may be suggested that the new techniques, such as the sterilisation of large quantities of air, are simply unit processes, to be added to the accepted curriculum of training of a chemical engineer. On the other hand SIR HAROLD HARTLEY, in the first lecture, with his usual eloquence and erudition, puts the case for regarding biochemical engineering as a new and distinct technique. As always his enthusiasm is very persuasive.

MR. F. E. WARNER (Chapter 2) writes on "The scope of biochemical engineering" in his customary forthright manner. His contribution to this symposium should have been larger, but his views on this topic are recorded at greater length elsewhere. He treats biochemical engineering under eight main headings. While his division may be debatable, in this book, as a whole, no one section is covered, and most of them receive no mention. His section 3 on training biochemical engineers should certainly have been elaborated. His statement that a graduate chemical engineer might find the acquisition of a biochemical background straightforward is sound, and is what usually happens. To train a biochemist in chemical engineering would certainly be, as he suggests, "an interesting experiment"!

The chapters on "Micro-organisms and their activities" and "Substrates for fermentation processes", written by experts and quite readable, go far beyond what a chemical engineer (whatever his prefix) would require to know. The following chapter on sterilisation of equipment, air and media gives a good picture of the problems as revealed by published work, but after eight pages on the sterilisation of air, for example, backed by an adequate bibliography, we are told that little has been published about the filters used on the large scale. One gathers from this chapter, and from a later one on "Recovery of fermentation products", that those authors who are engaged in industry could have divulged far more useful information, in fewer words, had they felt free to do so. In the "Recovery" chapter for example, it appears that the author is familiar with the use of SHARPLES and DE LAVAL separators in the penicillin process and has heard of the PODBIELNIAK machine. The LUWESTA mixer-separator used on the Continent for the identical stage of the process, is not mentioned however.

The chapter on "Equipment design" is pure chemical engineering and in line with present knowledge but incomplete. Many more references are available than those given. We note that "compressed air usually contains an oil which must be removed. . . ." The problem could not have been stated more simply. No answer is suggested. The author probably knows, but forgets to tell us, that compressors having carbon piston rings, and no lubricant in the cylinders, were widely used at one time. The last chapter on "Present trends and future developments" is the best written and most thought-provoking in the book. MR. HASTINGS is well known for his lectures on practical present-day problems in his field, but here, where philosophy is allowed to creep in, he reveals unsuspected depths of thought and mastery of language.

The bibliography is extensive (over 300 refs.) and the whole book is eminently readable. It is, and will continue to be, widely read and discussed.

B. EDGINGTON

Dispersion of Materials

by Rolt Hammond

Heywood & Co. Ltd., London, 1958, 229 pp., 40s.

THERE is a great need in Britain for textbooks dealing comprehensively with single topics in chemical engineering. There is no book, for instance, by a British author, devoted to distillation, nor for that matter is there any book in the English language dealing solely and exhaustively with drying. A series of text-

Continued on p. 634

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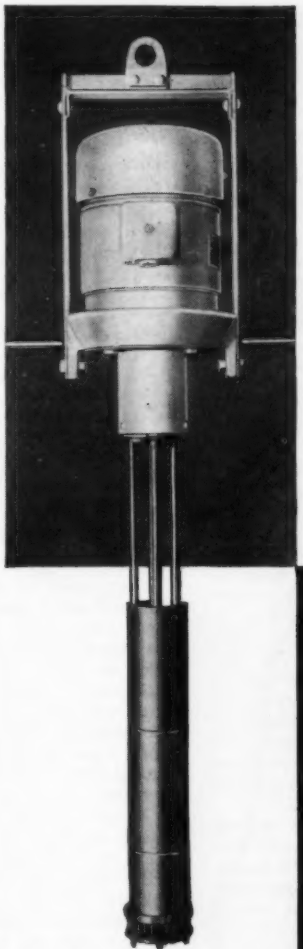

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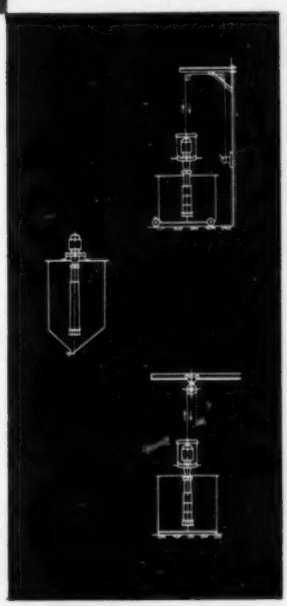

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Book Reviews (continued)

books dealing in detail with a variety of chemical engineering topics is therefore very welcome. In "Dispersion of Materials", the second volume of this series, MR. HAMMOND has produced a book which gives an excellent general review of crushing and grinding, classification, fluidisation, flotation, liquid dispersion, the dispersion of gases and atmospheric pollution. The result is a very readable book with many attractive features. Modern units of equipment are described in detail along with typical applications of the equipment. This is extremely useful to the student, as also is the list of manufacturers of the equipment. The text is admirably accompanied by many photographs and diagrams. The chapters on fluidisation and on flotation are especially good; the former gives a wide picture of the use of a comparatively new technique, while the latter deals clearly with the possibilities of flotation in the chemical industry.

The book is amazingly replete with information for its size and in any criticism of it, this must be borne in mind. Yet a textbook of this type should be exhaustive of the field covered and there are certain omissions. In the chapter on crushing and grinding, there is no mention of the British vibrating grinders now available nor of the use of fluid energy for fine grinding, while in the section on classification, rake classifiers, hydraulic jigs, riffled tables and centrifugal separators are omitted. There is no indication of the differing values obtained if dust removal efficiency is estimated by weight, by particle count or by the blackness staining test. One is surprised to find mixing left out, while the author includes in the chapter on the dispersion of gases and atmospheric pollution, fresh material on electrostatic precipitation, cyclones and gas washers which are covered adequately in his previous volume in the same series.

To the chemical engineering student, this text will give a valuable insight into the construction and use of the equipment described. To the experienced engineer, it will give a useful overall picture of modern developments in this field.

R. HENDRY

Absorption Spectrophotometry

by G. F. Lothian

Hilger & Watts, London, 1958, 246 pp., 52s.

THIS book is a completely revised version of the well-known first edition by the same author. Like its predecessor, it will be welcomed by student and teacher alike, both of whom are faced with the necessity of digesting and understanding the bewildering volume of research work produced over the last decade. The main emphasis of "Absorption Spectrophotometry" lies on the use of laboratory instruments and, as such, it will prove very useful. It would, however, be unfair to relate it to a process control setting. The principles utilised in both laboratory and process instruments are the same, but the latter are designed to meet severe environmental conditions and lose in elegance what they gain in robustness. Thus, this book, though a valuable introductory survey of the subject, would not prove readily amenable to the needs of, say, the instrument technician concerned with process analysis.

T. P. GRAY

The Physical Chemistry of Electrolytic Solutions—Third Edition

by Herbert S. Harned and Benton B. Owen

Reinhold Publishing Corp., New York and Chapman & Hall, London, 1958, 803 pp., 160s.

THIS book, one of the Monographs produced under the ægis of the American Chemical Society, has become a household word in electro-chemistry and references to "HARNED and OWEN" are both frequent and authoritative. The latest edition represents a revision of the text of 1943 and succeeds the interim edition of 1949 which served to introduce some of the new work then available, without the extensive revision that has now been achieved. The principal alterations have been the recalculation of various numerical coefficients to conform with recommendations of the National Research Council in 1952 on fundamental constants, and the inclusion in the text of sections on irreversible thermodynamics and the latest advances in conductivity theory.

The scope of the book is limited to a consideration of theoretical and experimental knowledge of the physical chemistry of electrolytic solutions. It excludes the study of chemical reactions which occur at electrodes, and the kinetics of reactions in solution. The electrolytic solutions dealt with are almost wholly aqueous ones. Molten and non-aqueous electrolytes are not treated, and a tendency to overlook the contribution of British workers is characterised by lack of reference to work by BOCKRIS, *et al.*, on solvation and salting-out—a subject which receives less attention than might be expected.

Accepting the outstanding merit of the text for use by electro-chemists, the needs of chemical engineers are not so well fulfilled. The 15 chapters are divided into five theoretical ones, from which no readily understood physical picture of an electrolytic solution emerges, and 10 experimental ones. The experimental chapters are each monographs in themselves and describe results of methods, rather than the techniques used. They are valuable for reference, and it is as such, rather than as a text book, that the work as a whole is likely to be of use to chemical engineers. The chapters on "Numerical Compilations", from which prediction of data in ranges outside experimental knowledge may be made, "Investigation of Irreversible Processes" and "Thermochemical Quantities" are of particular interest.

As often happens with revised editions, some dated parts of the book have escaped the authors' close scrutiny, such as the reference to a "recent" monograph by SWIETOSLAWSKI published in 1937, but the text as a whole is pleasantly free of errors. Although of limited use to chemical engineers, this book can be recommended as one of the most authoritative works of reference available on its subject.

R. G. H. WATSON

Non-destructive Methods for the Examination of Welds

T29/1. British Welding Research Association London, 1958, 78 pp., 7s. 6d.

THERE HAVE BEEN no epoch-making discoveries in the various fields of non-destructive testing since the earlier edition of this memorandum was published in March, 1952, but there have been numerous painstaking advances in detail and the memorandum, therefore, has been revised. Sections are headed radiographic methods, ultrasonic and other acoustical methods, magnetic methods, penetrant methods, gas leak detection method, proof test or overload test and semi-destructive methods. The volume is completed by appendices discussing the suitability of methods for application to various welded joints and listing the types of defects which each examination can reveal.

BRITISH STANDARDS

B.S. 2951:1958. Glossary of terms used in high vacuum technology. 7s. 6d.

ALTHOUGH THIS British Standard Glossary differs in detail from the United States Glossary, an effort has been made to ensure that, as far as possible, the same term is used with the same meaning. A number of terms which are used in the United States, but which are not generally accepted in the United Kingdom, have been included in an appendix. Where a number of terms have come into use with approximately the same meaning, the terms to be preferred have been selected for definition.

B.S. 2978: Part 1: 1958. Measurements of smoke emission from industrial boilers. Part 1: Medium-capacity coal-fired watertube boilers with travelling grates. 5s.

PARAGRAPH 35 of the Report of the Government Committee on Air Pollution (Cmd. 9322, November, 1954) contains the recommendation "that the following documents should be prepared and issued by the B.S.I.:

> (i) Codes of practice indicating the extent to which smoke can be reduced by good practice and the means of securing such reductions."

From the figures collected, it would appear that average emissions of dark smoke in excess of six minutes per shift per boiler can normally be avoided in water-tube boilers with travelling-grate stokers within the size range 30,000 lb./hr to 50,000 lb:/hr.

B.S. 598:1958. Sampling and examination of bituminous mixtures for roads and buildings. 12s. 6d.

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for remote control. The charge is moved by both a cascade and lateral action, the lateral distribution being obtained by pivoted chute plates fitted with differential linkages. **Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.1.**

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Vacuum Drier

The new Calmic C-3 vacuum drier, like their C-51 model, contains small independent compartments which enable drying to commence as soon as one compartment has been filled and to continue whilst others are being loaded and unloaded. It may be used, therefore, for semi-continuous operation. The vacuum chambers are small and the whole equipment can be operated by one man. Temperature is controlled accurately over the whole drying area it is pointed out. The C-3 is intended for drying low moisture-content materials, granules, powders, etc., and including materials giving off toxic and explosive vapours. The drier caters for temperature range from ambient to 150°C, and it normally operates at a vacuum of 20 mm absolute. Heat is by hot oil circulating between the compartments. Standard models contain two, four, six, eight and ten compartments and the tray area of each compartment is about 20 sq. ft. **Calmic Engineering Co. Ltd., Crewe, Ches.**

BCE 4142 for further information

Bolted Enamel Reactor

A unique feature claimed for Clark's standard glass enamelled reactors is the use of a bolted-on (instead of welded) mild-steel steam jacket. Four large openings are provided in the cast-iron cover. This method of fixing the jacket means that the inner pan can be readily removed and replaced and that re-enamelling can be carried out without fear of damage to the jacket. Mild-steel enamelled flanges are fitted on the four large main cover openings, which permit a wide variation in the arrangements of inlet openings, sight glasses, thermo pockets, baffles, etc. All contact surfaces are lined with Clark's hard glass enamel, which, it is pointed out, is resistant to severe acid conditions and hot alkaline solutions up to p_H 12. Impeller agitators with adjustable baffles are employed as standard in the reactor, but modifications can be made if required by the user. Full use has been made of P.T.F.E. for joints and in the packing of the water-cooled stuffing box. **T. & C. Clark & Co. Ltd., Shakespear Foundry, Wolverhampton.**

BCE 4143 for further information

New Diffusion Pump

A diffusion pump designed primarily to work at highest pumping speeds at lowest pressures has been introduced by Metropolitan-Vickers Electrical Co. The pump, type 9/14, is suitable for the large vacuum systems used in nuclear physics research, and it formed the basis of the equipment the company supplied for the evacuation of the Zeta torus. Available in oil and mercury versions, its characteristics are those of a 14-in diameter pump at pressures below 5×10^{-4} mm. Hg and of a 9-in. diameter pump at higher pressures (of the order of 10^{-5} mm. Hg) but with a power consumption of only 2.5 kW for the oil pump and 3 kW for the mercury pump. The peak, unbaffled air speed of the oil pump is 2850 l. a second, a far higher speed, it is pointed out, than that attained by conventional pumps with the same power consumption. The ultimate pressures at 15°C baffle temperature are less than 1×10^{-5} mm. Hg using Apiezon oil G, and less than 1×10^{-7} mm. Hg using Apiezon oil C. If the pump is used in conjunction with refrigerated baffles operating at −40°C, the limiting pressure is less than 5×10^{-8} mm. Hg. **Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.**

BCE 4144 for further information

Developments of Aircraft Pipe-fittings

Industrial equipment that Flight Refuelling have developed from aircraft devices include a series of pipe connectors that are constructed so that inner and outer sleeves, split collars and rubber seals can be assembled on to pipes already beaded. Seals are supplied in five kinds of rubber to cater for various fluids and temperatures. Each seal, which is chamfered at both ends and has two U-section grooves moulded into the bore, establishes a pressure-tight coupling between the two pipes. The connectors are made in pipe sizes $\frac{1}{2}$ to 5 in. o.d.

For certain specialised industrial purposes valves incorporating the basic components of the company's aircraft non-return valve, but housed in a flanged cast body, are in service. They are subjected to the severe test of a leak check with kerosene with only 0.10 in. head. The flexible rubber seal of the valve is backed by a stainless-steel shim cone. The company is also developing a quick-release bunkering connection for oils and other liquids from a naval coupling ordered by the Royal Navy. **Flight Refuelling Ltd., Tarrant Rushton Airfield, Blandford, Dorset.**

BCE 4145 for further information

Valve in Fluon

An all-Fluon valve for use with corrosive and hot liquids, including concentrated sulphuric and nitric acids and hot ferric chloride, has been introduced by the Chemical Pipe & Vessel Co. Its maximum working temperature is 200°C. Available in sizes of up to 2-in. bore, the valves are supplied with flanged ends, or with screwed ends for connecting with low-pressure lines. **Chemical Pipe & Vessel Co. Ltd., Godstone Road, Kenley, Surrey.**

BCE 4146 for further information

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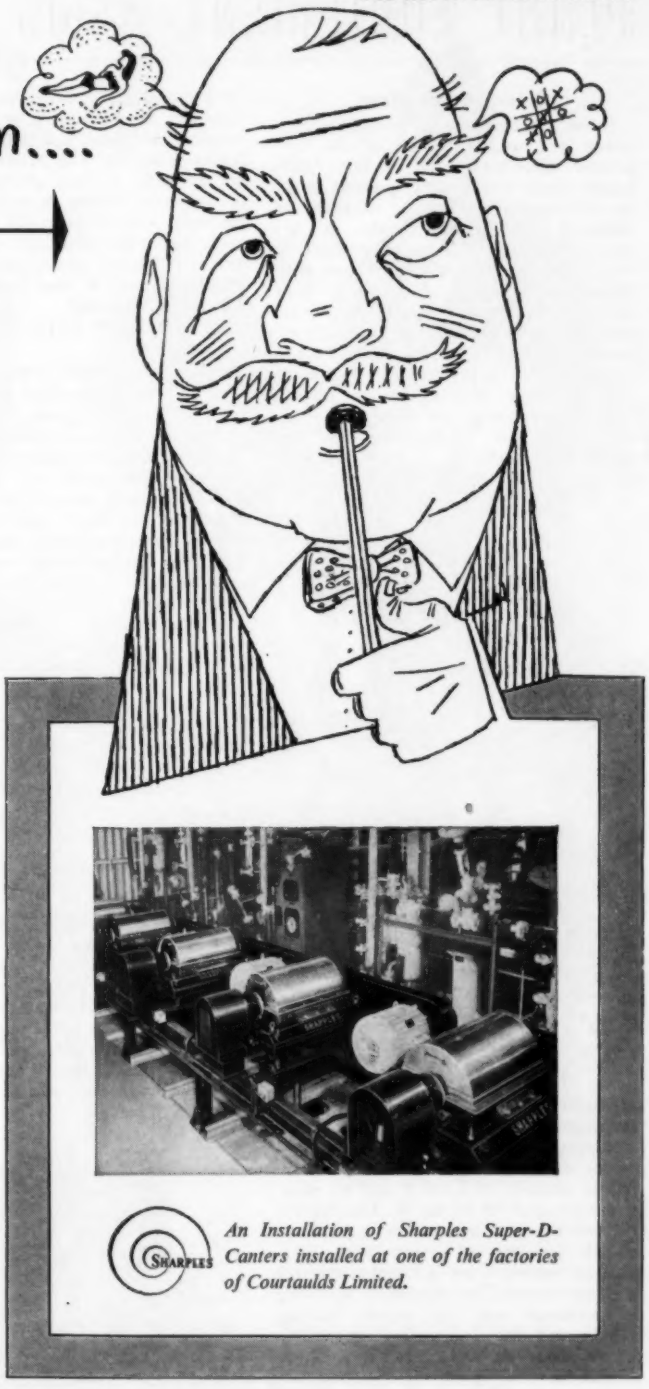

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BCE 4147 for further information

Hot-air Drying Cabinet

Mitchell's new hot-air drying cabinet is designed for steam or electric heating. Equipped with ten drying trays 32 in. × 16 in. × 1½ in. deep, it provides a volumetric capacity of 3 cu. ft and an effective tray area of 35 sq. ft. The control instruments are located in a separate cubicle for ease of maintenance. Variable air velocities are obtainable through a single control. The maximum operating temperatures are, by steam heating, 100°C, and by electric heating, 250°C. **L. A. Mitchell Ltd., 37 Peter Street, Manchester, 2.**

BCE 4148 for further information

Quantity-produced Pinch Valves

Die-cast construction for the casing and internal parts is a special feature of the new Rowe pinch valve, available in sizes from 1 to 3 in. bore diameter. The valves incorporate reinforced sleeves suitable for internal pressures of up to 100 psi. The casing of aluminium is split on its vertical axis for ease of assembly and servicing, and it completely encloses the flexible sleeve and operating mechanism. It is provided, as standard, with end flanges to B.S. specification table D. The reinforced sleeves are available in four grades of natural or synthetic rubber materials for, respectively, general purposes, alcohol and milk, petroleum products, tar and ammoniacal liquors, and abrasive materials. **W. H. Rowe & Son Ltd., Quayside Road, Southampton.**

BCE 4149 for further information

Swivel Joint

In Hilyn's new swivel pipe joint the internal pressure reacting upon the base of the moving part provides the sealing force between the mushroom section of the end connection and the P.T.F.E. seal. Additional support given by a tensioned spring ensures that even at very low pressures the swivel joint is pressure tight, the makers point out. Subjected to test pressures of up to 2500 psi, the joint remained secure and pressure tight while providing rotary movement through 360 degrees and an angular movement of 10 degrees. For usual industrial application the swivel joint can be used with pressures up to 500 psi (steam) and temperatures up to 485°F. They are available in sizes ¼ to 2 in. B.S.P. in elbow or straight patterns and, specially manufactured, in sizes up to 6 in. B.S.P. **Hilyn Industrial Equipment Ltd., Hilyn Works, Lockfield Avenue, Brimsdown, Enfield, Middx.**

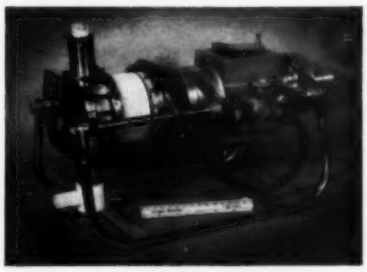
BCE 4150 for further information

Single-stage High-vacuum Pump

A new Kinney single-stage high-vacuum pump of duplex design is now being produced by General Engineering. It is the GKD.30 and freedom from vibration was a particular aim in its design. The pump comprises two single units enclosed in one housing and having a common suction and discharge. A single shaft passes through the centre wall with an eccentric cam keyed to the shaft on each side of the wall. Each stage has a piston around the cam with an integral hollow extension from the piston extending through a slide pin. In one side of the hollow extension on the piston are cored diagonal slots, which the slide pin covers and uncovers as the hollow extension slides up and down through it. This forms a positively-operated mechanical inlet valve. Each unit, the manufacturers point out, has two discharge valves of a new design, manufactured from close-grained cast-iron and stainless steel. **General Engineering Co. (Radcliffe) Ltd., Station Works, Bury Road, Radcliffe, Lancs.**

BCE 4151 for further information

Bellows Pump for Corrosive Chemicals



Crane Packing have developed a bellows pump for use with highly-corrosive chemicals, in which all parts which come into contact with the fluid are made of Fluon (polytetrafluoroethylene). Although basically designed for handling clear fluids, it can also function with liquids having solids in suspension so long as they do not silt up the convolutions of the bellows or prevent the valves operating. Intended mainly for use on short-term experiments or as a metering pump providing an infinitely variable flow over the delivery range, the pump is set to a predetermined pumping pressure by a reducing valve in the air supply. As a metering unit, an accuracy of ±2% has been consistently maintained in test runs. It can also be used in a production plant where service conditions are light. The pump has handled, for example, mixed hydrochloric and nitric acids and it is also suitable for handling very pure liquids such as triple-distilled water, or products where hygiene is of major importance. It can be cleaned and sterilised at 250°C. The established temperature range is −40°C to 80°C. A single-ended pump will deliver up to 28 gallons an hour. The double-ended model has twice the capacity. **PTFE Engineering Division, Crane Packing Ltd., Slough, Bucks.**

BCE 4152 for further information

Air-operated Pump

Air-motor-operated Versatal industrial pumps are now in production at the Harlow factory of Stewart-Warner. The range is suitable for a variety of fluids, including those containing abrasive materials. The design has been available in North America for some years, and the models now being made in Great

People who pride themselves on their good equipment speak of ENSECOTE in a personal way. ENSECOTE protective plastic linings can be applied almost anywhere to almost anything. They are easily cleaned and sterilised, completely odourless, tasteless—and economical to install because larger vessels can be lined on the spot. ENSECOTE is particularly useful, too, for renovating glass lined tanks. The Dairy, Brewing, Paper and Chemical Industries—and all who own rail and road storage tanks —will find ENSECOTE invaluable as a protection against wastage due to deterioration.

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THORNCLIFFE, NR. SHEFFIELD, ENGLAND
Agents in Belgium, France and Holland:
FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, SA., TRAZEGNIES, BELGIUM

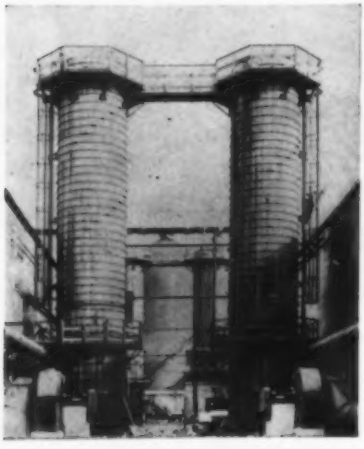
PLANT EQUIPMENT NEWS

Britain incorporate the latest developments. A typical Versatal system includes (1) an air-operated pump, which removes material from the original container and forces it (at desired pressure and rate of delivery) through (2) pipes, tubing or hose and (3) control valves. The operation is controlled at the point of application. **Alemite Division, Stewart-Warner Ltd., Elizabeth Way, Harlow, Essex.**

BCE 4153 for further information

Equipment in Wood

Wooden cylindrical scrubbers and pipelines developed since 1903 by the Santa Fe Tank & Tower Co., of California, are now available in the United Kingdom and British Commonwealth from Head Wrightson Processes through co-operation with the Santa Fe Division of their American associates, The Fluor Products Co. Of wood stave construction, the scrubbers are self-bracing and do not require supporting framework. They have been designed to provide a smooth internal surface for control of air turbulence and to allow for an efficient system of recovering essential gases for profitable use, and they contain no dead-air pockets, the manufacturers say, to retard performance. Head Wrightson are prepared to design the scrubbers to fit particular industrial purposes. Outside hardware is reduced to a minimum and can be supplied in hot-lead dipped steel, monel, stainless steel, brass and bronze. The spray systems are available in various materials. Where the process requires internal air straighteners or drift eliminators, both can be of wood. Santa Fe point out that their wooden pipeline installations have withstood years of service successfully. The pipes can be laid on the surface or buried. **Head Wrightson & Co. Ltd., 20 Buckingham Gate, London, S.W.1.**



BCE 4154 for further information

Mechanical Distiller

Mirrlees mechanical distiller consists of an evaporator vessel in which water is boiled; a rotary compressor and its driving unit to compress the vapour from the boiling water in the evaporator, thus giving a temperature difference across the tubes by virtue of the rise in temperature of the compressed vapour so that continuous boiling is maintained without any further outside source of heat; and heat exchangers to transfer heat to the ingoing feed from the outgoing condensed vapour and blowdown. The evaporator can be used to distil brackish or salt water. Where sea water is being distilled, however, especially with a high salts content, it is necessary to run the evaporator in conjunction with a brine stabiliser so that the scaling elements are kept out of the evaporator, allowing prolonged runs without the necessity for shutting down to clean. The salient advantage claimed for the plant is economy in operation. With diesel-driven plants, outputs of 180 to 200 lb. of distilled water per lb. of fuel are easily obtained, it is said, as use may be made of the cooling water jacket heat and the exhaust gas heat, which are normally wasted in diesel-engine running. **The Mirrlees Watson Co. Ltd., 45 Scotland Street, Glasgow, C.5.**

BCE 4155 for further information

Drum Mixer

A change-drum tumbler for dry colour blending and mixing phenolic materials has been introduced by Winkworth. Use is made in it of detachable disposable 50-gal. drums as standard but smaller drums can be accommodated, and it is also available with fixed drums for filling and emptying while they are held in machine. The machine is powered by a 1-hp motor and the drive is by heavy-duty roller-chain. **Winkworth Machinery Ltd., 65 High Street, Staines, Middx.**

BCE 4156 for further information

Mercury Collector

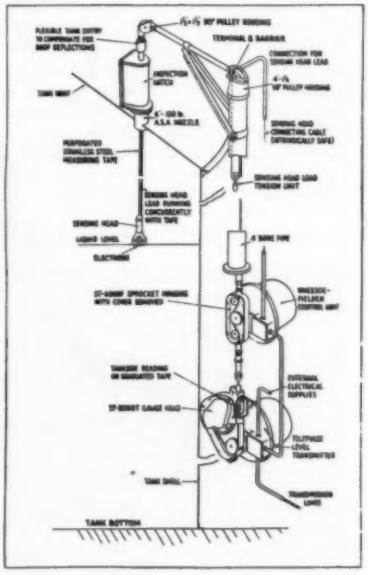
The new Polysyn mercury collector consists of a hexagonal container with a screwed top, a tray and a threaded lid with an inserted plastic foam pad. To collect mercury accidentally spilled, the lid and foam pad are removed from the container and are pressed against the surface on which the mercury has been spilled, covering the mercury globules. The pressure opens the cells in the pad so that the globules can enter them. They close once pressure is released and the lid can then be screwed back into the container. The pressure created by closing the container releases the mercury into the container. **Goodburn Engineering Co. Ltd., Arundel Road, Trading Estate, Uxbridge, Middx.**

BCE 4157 for further information

Instruments

Servo Tank Gauge

The Whessoe-Fielden servo tank gauge has been developed as an accurate instrument not affected by changes of specific gravity of the liquid or frictional losses. It consists of a level sensing head, suspended just above the liquid surface by a perforated tape. From the head the tape runs over two 90-degree pulleys at the top of the tank near ground level, and a tape storage and tensioning device provides an accurate tank-side reading.



A remote-level transmitter can be bolted to the side of the reading head if required. All components are supplied in vapour-tight housings and are available for working at either atmospheric pressure or for pressures up to 300 psig. The sensing head consists of a pressure-tight stainless-steel tube housing a transistorised oscillator amplifier and rigidly supporting an electrode plate. In operation this plate is located just above the level of the liquid. The transistorised oscillator feeds a capacitance bridge circuit, one arm of the bridge being formed by the electrode plate capacitance. All field circuits are either intrinsically safe or housed in flameproof enclosures. **Whessoe Ltd., Darlington.**

BCE 4158 for further information

Pipe-flow Calculators

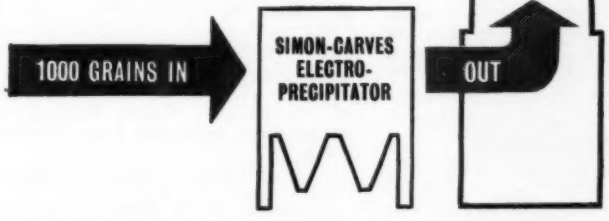
Two new circular slide-rule calculators for determining the flow of liquids and gases are being made by Fearns, Mear & Co. They have been designed to provide quickly and accurately the rate of flow, pressure drop or required pipe size for all fluids, one instrument dealing with turbulent flow and the other with the streamline flow of viscous liquids. They take into account viscosity and specific gravity and automatically allow for the established variation in the coefficient of friction according to the velocity and pipe size. The turbulent flow calculator is intended to deal with most practical cases, and it carries on the reverse side viscosity figures at various temperatures for a wide range of liquids, together with scales to confirm whether the flow is turbulent or streamline and

BCE 4088 for further information

PROOF of efficiency

SIMON-CARVES PRECIPITATORS AT C.E.G.B. POWER STATIONS

STATION	UNIT	EMISSION PER 1000 GRAINS PERMITTED UNDER GUARANTEE	EMISSION PER 1000 GRAINS MEASURED DURING TESTS
HUNCOAT	No. 1	20 GRAINS	5·7 GRAINS
HUNCOAT	No. 4	25 GRAINS	1·6 GRAINS
CHADDERTON 'B'	No. 2	20 GRAINS	5·6 GRAINS
CHADDERTON 'B'	No. 4	20 GRAINS	13·3 GRAINS
FLEETWOOD	No. 2	25 GRAINS	6·4 GRAINS
FLEETWOOD	No. 3	25 GRAINS	2·7 GRAINS
HACKNEY 'B'	No. 3	15 GRAINS	9·2 GRAINS *
ROGERSTONE	No. 2	25 GRAINS	4·4 GRAINS *



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PLANT EQUIPMENT NEWS

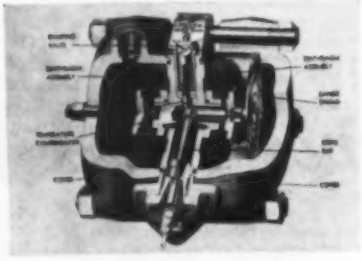
viscosity conversion scales. The instruments are suitable for calculations for pipes 0.1 in. to 40 in. in diameter passing from 0.1 to 1,000,000 gal. per hour. They are made in transparent and white Perspex with two-colour engraved scales. A similar instrument will shortly be available for dealing solely with the flow of water and covering large ducts,

brick sewers, open channels, etc., in addition to pipes of various materials. **Fearns, Mear & Co., 43 St. Helens Road, Almondbury, Huddersfield.**

BCE 4159 for further information

Differential-pressure Meter

A new mercury-less meter to measure differential pressures between 20 and 200 in. of water at static pressures of up to 2000 psi has been introduced by Foxboro-Yoxall. Among the advanced design features which are claimed for the instrument is an entirely new flexible diaphragm assembly composed of preformed discs welded and shaped to nest into the adjacent disc and welded to a spacing ring. Excess pressure in either chamber compresses the diaphragm assembly until each pair of discs is nested and the spacing rings have contacted to form a metal-to-metal stop. It is said that this assembly has greater flexibility and higher sensitivity per unit length, with less spring rate than any spun or hydraulically formed bellows for equivalent service. The drive unit is of solid rods joined by a metal flexure and forms a direct connection between the diaphragm assembly and the pen lever. Positive protection against over-range with no zero shift; a simple method of



range change; a built-in temperature compensation and full range damping which is adjustable under pressure are other features of the new product. **Foxboro-Yoxall Ltd., Redhill, Surrey.**

BCE 4160 for further information

Plant Control Instruments

As the result of an agreement recently concluded between Elliott Automation and Consolidated Electrodynamics Corp., of Pasadena, California, the Elliott Automation Group will manufacture a range of analytical and control instruments specifically designed by Consolidated for plant used. They include the process chromatograph, type 26-202 which is supplied as two units—an analyser in an explosion-proof housing which can be mounted close to the process stream, and the control unit which may be located remotely in the control room. Other instruments to be made available are the process refractometer, type 38-202, and the process moisture monitor, type 26-310, intended for the continuous measurement of moisture in gas process streams. It is of particular use where the measurement of extremely low concentrations of water vapour is required, and accurate measurement down to one part per million is claimed for the instrument. Its essential part is a patented electrolysis cell. Consolidated's mass spectrometer, 21-611, is capable of analysing both batch and continuous samples, and the oxygen analyser, type 38-301, which will also be available, operates on the proportional colour change of an oxygen-sensitive reagent when exposed to a gas containing oxygen. **Elliott Brothers (London) Ltd., Century Works, London, S.E.13.**

BCE 4161 for further information

Air-filter Gauges

An air-filter gauge by the American Air Filter Co., for which Air Control have been appointed distributors, gives automatically a visible warning when it is time to change filters on forced warm air furnaces, air conditioners, air cleaning units, humidifiers, unit heaters, unit ventilators, or other kinds of heating, ventilating or cooling equipment. **Air Control Installations Ltd., Ruislip, Middx.**

BCE 4162 for further information

Delivery Meter

A delivery meter in two designs—for respectively, mineral oils, etc., and solvents—is being made by British Central Electrical for use with their portable electric barrel-pumps. The meter is available in two sizes with a 3½-in. or a 5-in. dial and it is calibrated 0-25 gal. The pointer is easily set to zero for each measurement, but the register shows the total number of gallons pumped. The instrument is constructed of die-cast alloy. **British Central Electrical Co. Ltd., 6 Roseberry Avenue, London, E.C.1.**

BCE 4163 for further information

New Publications

Kent's publication 1008 provides a list of their organisations in over 60 countries and islands throughout the world. **George Kent Ltd., Luton, Beds.**

BCE 4164 for further information

Terylene for conveyor belting is the subject of two folders prepared by **Imperial Chemical Industries Ltd., Fibres Division, Hookstone Road, Harrogate, Yorks.**

BCE 4165 for further information

Hawker-Siddeley Nuclear Power Co. have published a survey of literature on nuclear engineering and related aspects entitled "Nuclear Power Progress, 1957". Articles reprinted in it include two from BRITISH CHEMICAL ENGINEERING, 1957, on the "Chemical Aspect of Nuclear Reactors" by J. Burkett. **Hawker-Siddeley Nuclear Power Co Ltd., Langley, nr. Slough, Bucks.**

BCE 4166 for further information

Publications recently issued by Neldco Processes describe their equipment for drying coal and ores which is manufactured and erected in the United Kingdom in co-operation with W. C. Holmes & Co., Huddersfield, and the dense media separation equipment built in the U.K. by Blantyre Engineering Co. Ltd., Blantyre, Glasgow. **Neldco Processes Ltd., Ashford, Middlesex.**

BCE 4167 for further information

The technical service of Henry Wiggin has published a booklet describing the properties of high-nickel alloys used in the construction of plant handling caustic soda. Some typical applications are illustrated and performance data are suppl'ed. The publication is of 51 pages, 9 in. by 6 in. **Henry Wiggin & Co. Ltd., Wiggin Street, Birmingham, 16.**

BCE 4168 for further information

Drytube dust filters are the subject of a four-page folder recently published by Dallow Lambert. Filters of widely-differing capacities are illustrated. **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 4169 for further information

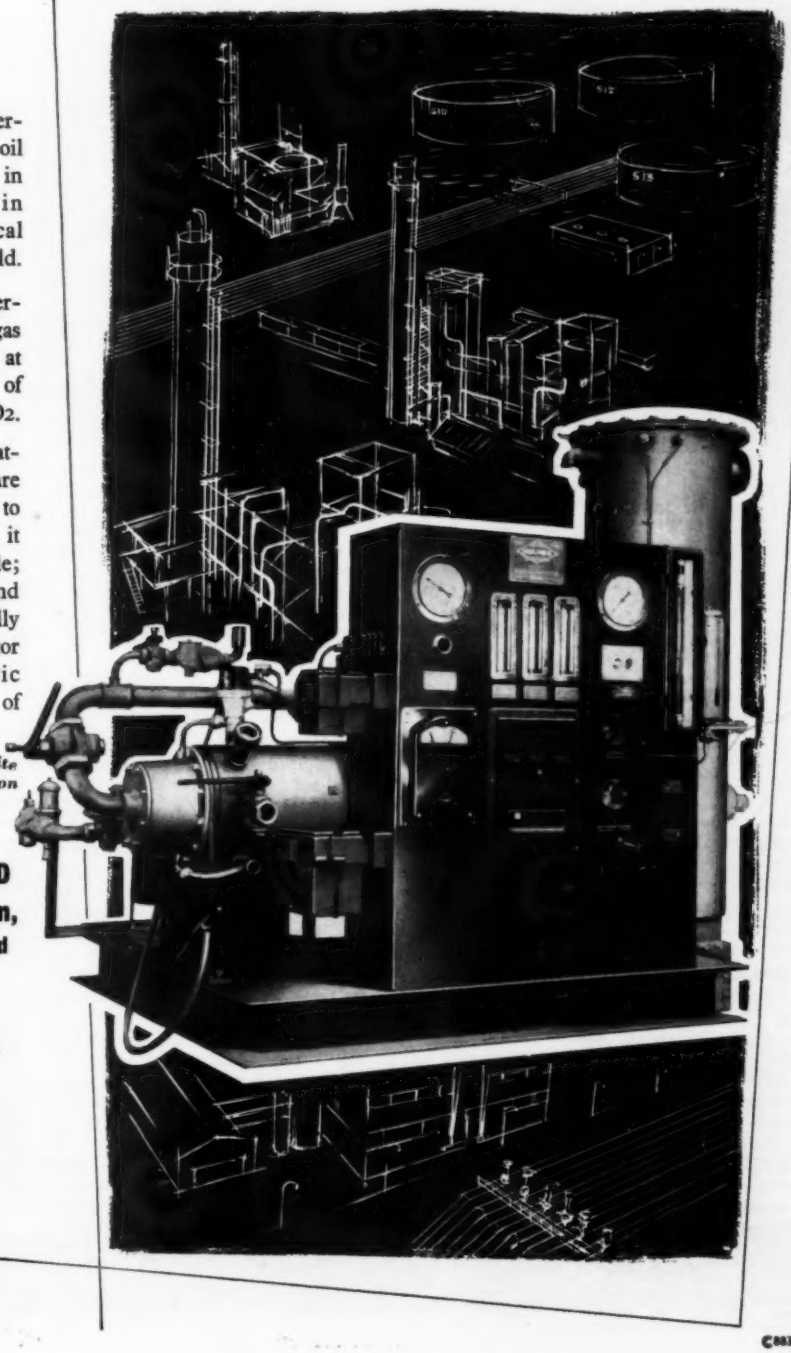
The October 1958-April 1959 seminar programme of the British Institute of Management lists 25 conferences to be held throughout Great Britain dealing with finance, general and office management, marketing, personnel problems and production. The courses are intended for managers at all levels and in all sizes of organisations. **British Institute of Management, 80 Fetter Lane, London, E.C.4.**

BCE 4170 for further information

"Platinum in the Glass Industry" is the title of a 48-page illustrated booklet prepared by Professor H. Moore and issued by the Mond Nickel Co. Among the 14 sections are chapters dealing with the experiments in the control of the temperatures of glass melt with thermocouples and the production of glass fibre for heat insulation and other purposes. **The Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1.**

BCE 4171 for further information

Inert Gas for Industry



Holmes Inert Gas Generators, both gas and oil fired, are being used in increasing numbers in refineries and chemical plant throughout the world.

By the use of such a generator high quality inert gas can be produced on site at a fraction of the cost of bottled gases or of solid CO_2.

The advantages of generating inert gas in this way are obvious; it can be piped to any point on site where it will be instantly available; it can be compressed and stored; supplies are virtually unlimited and the generator being fully automatic requires a minimum of maintenance.

For full details please write for a copy of Publication No. 64/34

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Month's News in Brief

Expansion of Training Colleges

The Government has recently announced its decision to increase the capacity of teacher training colleges. As an immediate step, 12,000 new places will be provided in the colleges. This to be completed by the autumn of 1962 at a cost of about £15 million. This is an increase of about 50% and is the largest programme which can be completed in the time available. It is designed to make possible the introduction of a three-year training in 1960 with the minimum of interference with the annual output of teachers from the colleges. Within the programme special measures will be taken to train extra teachers of science and mathematics. The governors of existing colleges are being asked to submit, as early as possible, their proposals for expanding their premises. About 50 existing colleges will be expanded and some more than doubled in size. Several new colleges will be built and sites for these are being considered. The extensions will be concentrated in the main on colleges capable of being enlarged to hold 400 or 500 students, and the new colleges will also be of about this size. Proposals will be specially encouraged which increase the number of mixed colleges, taking men and women students.

Call to Industry

If the Government's plans to expand and improve our system of technical education are to succeed, then industry and the trade unions must give them all possible support. This is the overriding theme of a booklet (*Britain's Future and Technical Education*) now going out to industry and commerce, industrial organisations and local educational authorities. Published by the Ministry of Education, the booklet describes how the technical colleges in England and Wales are being developed and how employers and trade unions can best assist to ensure the success of the Government's plans. In a foreword to the booklet, Mr. Geoffrey Lloyd, the Minister of Education, assesses the situation concisely when he says: "This is a tremendous once-for-all opportunity for remedying our shortages of skilled manpower ... its success, however, depends, on the co-operation and support of industry."

Anglo-Dutch Trade Council

The Federation of British Industries and the Association of British Chambers of Commerce have formed the Anglo-Dutch Trade Council to foster Anglo-Dutch trade. To testify to the importance of this new venture, the chairmen are two of the leading industrialists in their respective countries: Mr. Duncan Oppenheim, chairman of the British-American Tobacco Co., and Dr. Paul Rykens, lately chairman of Unilever N.V. of Holland, while H.M. Ambassador in The Hague, H.E. Sir Paul Mason, K.C.M.G., K.C.V.O., has consented to become the Council's honorary president. The address of the Council is 99 Jan Van Nassaustraat, The Hague, Holland. The Secretary is Mr. H. N. Schepp.

Among the British founder-members of the Council are B.I.P. Chemicals Ltd., Birmingham; B. W. Blydenstein & Co., London; B.P. Trading Ltd., London; The British Thomson-Houston Co. Ltd., Rugby; Brush Group Services Ltd., London; The Cement Marketing Co. Ltd., London; Cockburns Ltd., Glasgow; The Distillers Co. Ltd., London; Doulton & Co. Ltd., London; Drysdale & Co. Ltd., Glasgow; Ductube Co. Ltd., London; Dunlop Rubber Co. Ltd., London; The English Electric Co. Ltd., London; Esso Petroleum Co. Ltd., London; Felco Hoists Ltd., London; The General Electric Co. Ltd., London; Guest, Keen & Nettlefolds Ltd., Smethwick; James Howden & Co. Ltd., Glasgow; Imperial Chemical Industries Ltd., London; Johnson, Matthey & Co. Ltd., London; Lincoln Electric Co. Ltd., Welwyn Garden City; Metropolitan-Vickers Electrical Export Co. Ltd., London; Newton Chambers & Co. Ltd., Thorncliffe; Pilkington Bros. Ltd., St. Helens; Saunders Valve Co. Ltd., Cwmbran; Shell Petroleum Co. Ltd., London; Unilever Ltd., London; and G. & J. Weir Ltd., Glasgow.

Whessoe's New Division

Whessoe Ltd. announce the regrouping of departments concerned with design, tendering and development to form an engineering division. This new division will parallel the existing works and erection divisions which are concerned with shop fabrication and site construction, and it will comprise three engineering groups (storage, pressure vessels and chemical engineering), each of which will embrace all staff and activities associated with a range of related products.

News Briefs

Imperial Chemical Industries Ltd. and Celanese Corporation of America have formed a company (in which they will have equal shareholdings) for the purpose of manufacturing in the United States a polyester fibre that is chemically the same as "Terylene", the well-known polyester fibre manufactured in the United Kingdom by I.C.I.'s Fibres Division. The location of the plant to manufacture the fibre has not yet been decided. The plant is expected, however, to have an eventual capacity of 40 million lb. a year.

Birlec Ltd. and Efco Ltd. announce that negotiations between them for the formation of a new company, to take over certain sections of their business, have reached an advanced stage. It is intended that the new company shall be called Birlec-Efco (Melting) Ltd., and that its offices shall be near Birmingham, at Aldridge, Staffs. The intended scope of the company is the design and supply of all types of electric melting furnaces for the ferrous and non-ferrous metals industries, together with smelting furnaces and induction heating equipment. Both companies will continue independently to manufacture their respective heat-treatment furnaces and other plant.

The Mine Safety Appliances Co., one of the first American companies to establish itself in Scotland after the war, is to commence the manufacture of a complete range of new safety appliances at present obtainable only in the United States. The company has extended its range of products over the last eleven years to inclue 60 items of interest to mining and industry generally. These items are now produced in the company's factory at Queenslie Industrial Estate, and next month they hope to manufacture more of the 3600 items produced in the main factory at Pittsburgh, Pennsylvania.

British Arca Regulators moved on October 6, 1958, from Millbank, London, S.W.1, to Sisson Road, Gloucester, where all administrative functions and the manufacture of light engineering products will be carried out. Their works at Ledsam Street, Birmingham, will continue the manufacture of all heavy equipment.

K.D.G. Instruments Ltd. have opened a London sales and service office and showroom at 100 Fleet Street, London, E.C.4. Tel.: FLEet 5354.

A 16-mm. black-and-white film on King materials-handling systems and their application with a technical commentary by John Snagge has been announced by Geo. W. King Ltd. Copies of this film are available on loan, free of charge, to works, technical associations and similar organisations, on application to Geo. W. King Ltd., Argyle Works, Stevenage, Herts.

The Scientific Film Association has moved to new offices at 3 Belgrave Square, London, S.W.1. Tel.: BELgravia 6188.

People in the News

Mr. George Campbell has been appointed general manager of the Chemical and Metallurgical Division of The Plessey Co. Ltd. He was previously technical manager and deputy general manager of the company's Towcester plant. A graduate of Glasgow University with first-class honours in chemistry and metallurgy, Mr. Campbell joined Plessey's in 1945 and became head of the Swindon Division's laboratories and later pilot-plant manager at Towcester.

George Campbell.

J. Trevor-Jones.

M. & W. Grazebrook Ltd., of Dudley, Worcestershire, announce that, for health reasons, **Mr. A. C. Brooks** is retiring from

BCE 4090 for further information

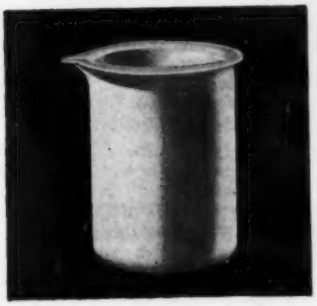
We are helping the chemical industry to discover new uses for PTFE every day. Its advantages for pipes, conduits, liners, moulded and machined components have always been obvious, but up to now the principal bottleneck has been the difficulty of producing it in the required shapes.

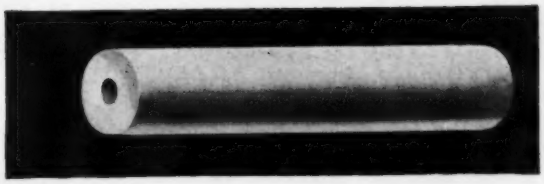
Siemens Ediswan, first and certainly the largest fabricators of PTFE in this country, have developed their facilities for extruding and machining PTFE into practically every basic form or shape required by makers or users of chemicals. If there is a process in your plant where product adhesion, corrosion, or solvent action is causing hold-ups and frequent replacement, send us particulars of the trouble. It is almost certain that we can help you. In any event, you ought to have the Siemens Ediswan brochure on PTFE by you for reference. We shall be delighted to send you a copy.

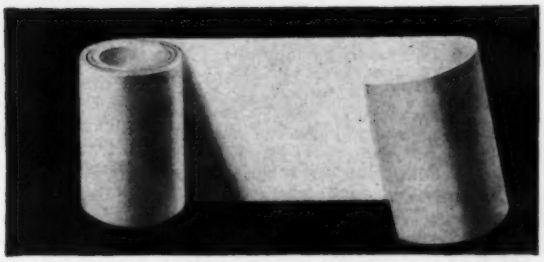
SIEMENS EDISWAN CLIX PTFE

nothing* dissolves corrodes sticks to PTFE

* *The one exception does not occur in normal industrial chemical processes.*







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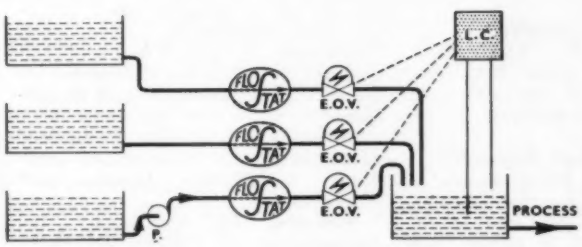
CRC17/10

FLOSTAT

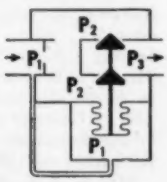
THE FLOW CONTROLLER WHICH IS SELF-ACTING

for Accurate Blending



e.g. Three liquids are mixed in the ratio 1 : 10 : 100 each being fed by gravity (or pumped) to a header tank through a "FLOSTAT" and an electrically operated valve. A level controller in the tank opens the valves simultaneously at low level and closes them at high level. In spite of rapidly changing demand for mixture its composition continuously meets stringent analytical tests.

The accurate blending of fluids is simple and inexpensive by the Flostat method. It is used for processes of dilution, combustion, catalysis, emulsification and batch mixing as well as all chemical reactions involving the proportioning of fluids. Hand operation by lever operated linked cocks can be provided or the fully automatic scheme illustrated. For accurate batching the electrically operated valves can be controlled from a process timer.



The Flostat combines in one body a differential-pressure flowmeter and a double-beat control valve. It is operated by the pressure energy of the fluid, and requires no outside power supply.

SOLE MANUFACTURERS: **G. A. PLATON LTD.** Technical Service for Industry
323A, WHITEHORSE ROAD, CROYDON, SURREY. Telephone: THOrnton Heath 1631

BCE 4091 for further information

the active control of day-to-day management of the company. Mr. Brooks will remain a director and will also be available as consultant. **Mr. J. Trevor-Jones**, a member of the board, has been appointed sales director.

Monsanto Chemicals Ltd. announce the appointment of **Mr. D. C. M. Salt** to the newly-created post of general manager in charge of Chemicals Division and of **Mr. G. Dodd** to the corresponding post of general manager in charge of Plastics and Special Products Division. Both general managers will be responsible to the managing director, **Mr. D. R. Mackie**.

Edgar Allen & Co. Ltd. have announced the following appointments in their Engineering Department: **Mr. J. Higginbotham** as deputy general manager; **Mr. J. D. Studholme** as assistant general manager; **Mr. A. Brunton** as commercial manager; **Mr. A. Wallis** as chief draughtsman (Production); **Mr. J. D. Lee** as chief draughtsman (Development); and **Mr. S. Carter** as chief estimator.

British Titan Products Co. Ltd. announce the appointments of **Mr. N. D. Harris**, **Dr. P. A. Lintern** and **Mr. S. G. Tinsley** as directors. Dr. Lintern and Mr. Tinsley have been with the company for many years, while Mr. Harris was formerly chairman of I.C.I. (India) Ltd.

Ashmore, Benson, Pease & Co., of Stockton-on-Tees, have announced the following new appointments: **Mr. G. B. Taylor** as sales manager (works division) and **Mr. R. H. Foster** as works manager.

Mr. S. H. Griffiths, head of John Thomson Ltd. group research laboratories, has been appointed a director of John Thompson (Wolverhampton) Ltd. Mr. Griffiths is a council member of the Institute of Welding and a past chairman of its Wolverhampton branch; a member of the Iron and Steel Institute; and he sits on several committees of the British Welding Research Association.

George Kent Ltd. announce the appointment of **Mr. T. P. W. Norris** as deputy chairman. They also announce that **Mr. R. E. Handford**, deputy managing director, after 45 years in the company's service, has relinquished his executive functions but retains his seat on the board; that **Mr. W. A. Hartop** has been appointed as managing director; and that **Commander P. W. Kent**, formerly chairman and managing director, remains chairman.

An amalgamation has been effected between The Hydronyl Syndicate Ltd. and Weinreb & Randall Ltd. **Mr. D. G. Randall** has been appointed technical director of Hydronyl, **Dr. R. Lessing** remains managing director and **Mr. W. J. Browning** commercial director. In future all inquiries should be sent to The Hydronyl Syndicate Ltd., 14 Gloucester Road, London, S.W.7. Tel.: KNIghtsbridge 6803.

Mr. A. J. C. Hoskyns-Abrahall, vice-chairman of Van den Berghs & Jurgens, has been elected chairman and managing director. **Mr. J. F. Knight** has resigned these positions.

The Minister of Power has appointed **Sir Alexander Fleck** to be chairman of his Scientific Advisory Council.

Metal & Pipeline Endurance Ltd. announce that **Mr. M. Gordon** has been appointed acting chief welding engineer in place of **Mr. R. B. Whalley**, who has resigned. Mr. Gordon has been deputy chief welding engineer with MAPEL for two years.

Mr. G. S. Cope has been appointed general manager of Freeman, Taylor Machines Ltd., Necton Street Works, Syston, Leicestershire. Mr. Cope, who joined the firm three years ago, will be responsible for sales and production.

Mr. W. H. Glass, who has been a director of Thermotank Ltd., the air-conditioning engineers (Helen Street, Glasgow) for the past 25 years, has retired from the board of the company.

Meetings of the Month

Institution of Chemical Engineers

October 18. *Midlands Branch:* At the Derby Technical College. "Flow Patterns in the Hydraulic Cyclone and their Interpretation in Terms of Performance", by D. Bradley and D. J. Pulling. **3 p.m.**

October 21. *London:* At the Geological Society, Burlington House, London, W.1. "Exploratory Study of the Flow of Granules through Apertures", by R. L. Brown and J. C. Richards. **5.30 p.m.**

October 28. *North-western Branch:* At the Blossoms Hotel, Chester. "Continuous Manufacture of Copper Sulphate", by F. G. Molyneux. **7 p.m.**

November 11. *North-western Branch:* At the Chemical Engineering Building, Manchester College of Science and Technology, Jackson Street, Manchester. "The Design and Operation of Refrigeration Plant in the Chemical Industry", by D. M. Elliott and R. Parkins. **6.30 p.m.**

November 19. *Midlands Branch:* At the Birmingham College of Technology, Gosta Green, Birmingham. "Chemical Engineering Aspects of Tar Acid Recovery", by D. McNeil. **6.30 p.m.**

November 19. *North-western Branch:* At Leeds. "Intersurface Reactions in Corrosion", time and place to be announced.

Institute of Petroleum

October 23. *London:* At 61 New Cavendish Street, London, W.1. "The Petroleum Industry in A.D. 2000", by Professor E. S. Sellers. **5.30 p.m.**

Incorporated Plant Engineers

October 28. *South Wales Branch:* At the South Wales Engineers' Institute, Park Place, Cardiff. "The Clean Air Act and Effluents", by A. S. Minton. **7.30 p.m.**

October 30. *Sheffield and District Branch:* At the Grand Hotel, Sheffield. "Planned Maintenance with Particular Reference to Breakdowns", by O. L. Pollack. **7.30 p.m.**

October 31. *Birmingham Branch:* At the Imperial Hotel, Temple Street. "Clean Air Act". **7.30 p.m.**

Society of Instrument Technology

October 20. At Manson House, Portland Place, London, W.1. "A simple Data Read-out System", by G. P. Tonkin. **5.30 p.m.**

November 13. *Grangemouth Section:* At Leapark Hotel, Grangemouth. "Temperature Measurement", by R. Postle. **7 p.m.**

November 19. *Newcastle Section:* At King's College, Stephenson Buildings, Newcastle upon Tyne. "Flow Measurement with Particular Reference to the Dall Tube", by D. H. Kent. **7 p.m.**

November 28. *Scottish Section:* At the Scottish Building Centre, 425 Sauchiehall Street, Glasgow. "Analytical Instrumentation of Chemical Processes", by J. D. Tallantire. **7.15 p.m.**

October 30. *Tees-side Section:* At the Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough. "The Place of Instrument Technology in Control Engineering", by Sir Harold Hartley. **7.30 p.m.**

Scientific Film Association

October 29. At the Messanine Cinema, Shell-Mex House, Strand, London, W.C.2. "Scientific Films in the Soviet Union." Members of the British Delegation to the 12th Congress of the International Scientific Film Association report on their impressions of the recently held Congress in Moscow.

Coming Events

Home

October 21. *Engineering Industries Association, The Eleventh London Regional Display:* At the Royal Horticultural Society's New Hall, Greycoat Street, and Old Hall, Vincent Square, London, S.W.1, **until October 23.**

October 21. *The Fourth Reinforced Plastics Technical Conference, organised by the British Plastics Federation:* At the Hotel Metropole, Brighton, **until October 24.**

October 28. *One-day Symposium on Aluminium Pressure Vessels:* At the Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W.1.

November 6. *Scientific Instrument Manufacturers Association's 1958 Convention:* At the Majestic Hotel, Harrogate, **until November 9.**

November 10. *Electro-heat and Productivity Exhibition and Conference:* At the Kelvin Hall, Glasgow, **until November 14.**

November 10. *Public Works and Municipal Services Congress and Exhibition:* At Olympia, London, **until November 15.**

November 24. *Symposium "The Mechanisation of Thought Processes":* At the National Physical Laboratory, Teddington, Middlesex, **until November 27.**

Overseas

November 16. *International Conference on Scientific Information:* At the Mayflower Hotel, Washington, D.C., U.S.A., **until November 21.**

November 17. *Society of the Plastics Industry. Eighth National Plastics Exposition:* At the International Ampitheater, Chicago, Ill., **until November 21.**